FORM PTO-1390 (REV 11-2000) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY 'S DOCKET NUMBER 3219
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U S APPLICATION NO. (If known, see 37 CFR 1.5 09/913708

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/00314	January 17, 2000	February 23, 1999

TITLE OF INVENTION
APPARATUS AND METHOD FOR PRODUCING A DATA STREAM AND APPARATUS AND METHOD FOR READING A DATA STREAM

APPLICANT(S) FOR DO/EO/US
SPERSCHNEIDER et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [X] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is attached hereto (required only if not communicated by the International Bureau).
   b. [ ] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. [XX] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   b. [ ] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (Unsigned)
10. [ ] An English lanugage translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [X] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [X] A substitute specification.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [X] Other items or information: Postcard Receipt, Misc. PCT Notices, Cert. of Mailing (Express)

JC03 Rec'd PCT/PTO 16 AUG 2001

U.S. APPLICATION NO (if known, see 37 CFR 1.5) 09/913708	INTERNATIONAL APPLICATION NO PCT/EP00/000314	ATTORNEY'S DOCKET NUMBER 3219

21. [X] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):

	CALCULATIONS	PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1000.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$860.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	15 - 20 =	0	x **$18.00**	$ 0	
Independent claims	4 - 3 =	1	x **$80.00**	$ 80	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$270.00**	$	
TOTAL OF ABOVE CALCULATIONS =				$ 940	
[ ] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. +				$	
SUBTOTAL =				$ 940	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$ 940	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 940	
				Amount to be refunded:	$
				charged:	$

a. [ ] A check in the amount of $ ________ to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________ in the amount of $ ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [ ] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. ______ . A duplicate copy of this sheet is enclosed.

d. [XX] Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

Ralph H. Dougherty
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SIGNATURE

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NAME

25,851
REGISTRATION NUMBER

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Docket 3219

Certificate of Mailing by "Express Mail"

I, Patricia Summers, do hereby certify that the foregoing or attached documents are being deposited with the United States Postal Service as Express Mail, postage prepaid, in an envelope addressed to: BOX PATENT APPLICATION, Commissioner of Patents and Trademarks, Washington, D.C. 20231 on August 16, 2001.

Patricia Summers

Name: Patricia Summers

Express Mail Label Number EL 873243742 US

August 16, 2001

Date of Deposit

09913708

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
PATENT OPERATIONS

Art Unit: (Examiner)

Applicants: SPERSCHNEIDER et al.

Serial No:

Filed:

Title: APPARATUS AND METHOD FOR PRODUCING A DATA STREAM AND APPARATUS AND METHOD FOR READING A DATA STREAM

Charlotte, North Carolina
August 16, 2001

Honorable Commissioner of Patents
Washington, DC 20231

Dear Sir:

PRELIMINARY AMENDMENT

Preliminary to Examination of the above-identified application, kindly amend the application as follows:

In the Specification:

Please substitute the attached specification for the translation of PCT Application PCT/EP00/00314 filed on January 17, 2000, with the European Patent Office.

In the Claims:

Please substitute the attached claims for those included in the translation of PCT Application PCT/EP00/00314 filed on January 17, 2000, with the European Patent Office.

REMARKS

Entry of the Amendment substituting the attached substitute specification and claims is respectfully requested by Applicant.

Respectfully submitted,

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Attorney's
Docket 3219

~~sub st~~ OIPE specification

National Phase of PCT/EP00/00314 in U.S.A.

Title: Apparatus and Method for Producing a Data stream and Apparatus and Method for Reading a Data stream

Applicants: SPERSCHNEIDER; DIETZ; HOMM; BÖHM

Final version of PCT/EP00/00314 for the prosecution at the USPTO to be filed as first preliminary amendment

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09/913708
JC03 Rec'd PCT/PTC 16 AUG 2001

Apparatus and Method for Producing a Data stream and Apparatus and Method for Reading a Data stream

Field of the Invention

The present invention relates to encoding with code words of variable lengths and, in particular, to producing and reading data streams with code words of variable lengths, which are robust with regard to errors in transmission.

Background of the Invention and Prior Art

Modern audio encoding or decoding methods which work by the MPEG layer 3 standard, for example, are capable of compressing the data rate of audio signals, e.g. by a factor 12, without noticeably degrading the quality thereof. In order to achieve such a high data rate reduction, an audio signal is sampled, whereby a sequence of discrete-time samples is obtained. As is known in the art, the sequence of discrete-time samples is windowed in order to obtain windowed blocks of time samples. A block of time-windowed samples is then transformed to the frequency range by means of a filter bank, a modified discrete cosine transform (MDCT) or other suitable device, in order to obtain spectral values which, as a whole, represent the audio signal, i.e. the time section determined by the block of discrete-time samples, in the frequency range. Usually, time blocks which overlap at 50% are produced and transformed to the frequency range by means of a MDCT whereby, due to the specific properties of the MDCT, 1024 discrete-time samples, for example, always lead to 1024 spectral values.

It is known that the receptivity of the human ear depends on the momentary spectrum of the audio signal itself. This dependency is covered in the so-called psycho-acoustic

model by means of which it has been possible for quite some time to calculate masking thresholds depending on the momentary spectrum. Masking means that a specific tone or a spectral component is hidden in case an adjacent spectral range, for example, has relatively high energy. This fact of masking is utilized in order to quantize as closely as possible the spectral values present after the transformation. The aim is therefore to avoid audible interferences in the re-decoded audio signal on the one hand and to use as few bits as possible on the other hand in order to encode or, in this case, to quantize the audio signal. The interferences introduced by quantization, i.e. quantization noise, are intended to be below the masking threshold and, therefore, to be inaudible. In accordance with known methods, a classification of the spectral values in so-called scale factor bands is carried out, which should correspond to the critical bands, i.e. frequency groups, of the human ear. Spectral values in a scale factor group are multiplied by a scale factor in order to carry out overall scaling of spectral values of a scale factor band. The scale factor bands scaled by the scale factor are then quantized, whereupon quantized spectral values are produced. It is understood that grouping in scale factor bands is not critical. However, it is used in the MPEG layer 3 standards or in the MPEG 2 AAC standard (AAC = advanced audio coding).

A very essential aspect of data reduction lies in entropy encoding of the quantized spectral values, which follows quantizing. Huffman encoding is usually used for entropy encoding. A Huffman coding is understood to mean a coding with a variable length, i.e. the length of the code word for a value to be encoded is dependent on the probability of occurrence thereof. Logically, the most probable character is assigned the shortest code, i.e. the shortest code word, so that very good redundancy reduction can be achieved by means of Huffman encoding. An example for a

generally-known coding with a general length is the Morse code.

In the field of audio encoding, Huffman codes are used for encoding the quantized spectral values. A modern audio encoder, which works, for example, in accordance with the MPEG 2 AAC standard, uses different Huffman code tables for encoding the quantized spectral values, which Huffman code tables are assigned to the spectrum by certain criteria on a section-by-section basis. In this process, 2 or 4 spectral values are always encoded together in one code word.

One difference between the method in accordance with MPEG 2 AAC and the method in accordance with MPEG layer 3 is that different scale factor bands, i.e. different spectral values, are grouped into any number of spectral sections. With AAC, one spectral section includes at least four spectral values, but preferably more than four spectral values. The entire frequency range of the spectral values is therefore divided up into adjacent sections, with one section representing one frequency band such that all sections together cover the entire frequency range, which is superimposed by the spectral values after the transformation thereof.

As in the MPEG layer 3 method, one section is assigned to a so-called "Huffman table" from a plurality of such tables in order to achieve a maximum redundancy reduction. In the bit stream of the AAC method, which usually comprises 1024 spectral values, are now the Huffman code words for the spectral values in an ascending order of frequencies. The information on the table used in each frequency section is transferred in the side information. This situation is shown in Fig. 6.

Fig. 6 shows the exemplary case where the bit stream includes 10 Huffman code words. In case one code word is

always formed from one spectral value, 10 spectral values may be encoded here. However, usually 2 or 4 spectral values are always jointly encoded by one code word, which is why Fig. 6 shows a part of the encoded bit stream which includes 20 or 40 spectral values. In the case where each Huffman code word includes 2 spectral values, the code word designated by No. 1 represents the first two spectral values, with the length of code word No. 1 being relatively short, which means that the values of the first two spectral values, i.e. of the two smallest frequency coefficients, occur relatively frequently. The code word bearing the No. 2, however, has a relatively long length, which means that the amounts of the 3rd and 4th spectral coefficients in the encoded audio signal are relatively rare, which is why they are encoded with a relatively large amount of bits. Further, it is apparent from Fig. 6 that the code words with the numbers 3, 4 and 5, which represent the spectral coefficients 5 and 6 or 7 and 8 or 9 and 10, also occur relatively frequently, since the length of the individual code words is relatively small. The same applies to the code words bearing the numbers 6 to 10.

As has already been mentioned, it is clearly apparent from Fig. 6 that the Huffman code words for the encoded spectral values are arranged in the bit stream in a linearly ascending manner with regard to the frequency in case a bit stream which is produced by a known encoding apparatus is considered.

One major drawback with regard to Huffman codes, in the case of faulty channels, is error propagation. It may be assumed, for example, that code word No. 2 in Fig. 6 is interfered with. There is a certain, not low, probability that the length of this wrong code word No. 2 is also modified. It therefore is different from the correct length. In case, in the example of Fig. 6, code word No. 2 has been modified in its length due to an interference, it is no longer possible for an encoder to determine the

starts of the code words 3 to 10, i.e. of almost the entire audio signal represented. This means that all other code words following the code word which has been interfered with can no longer be correctly encoded, since it is not known where these code words start, and since an incorrect starting point was selected due to the error.

As a solution to the problem of error propagation, European Patent No. 0 612 156 proposes that a part of the code words of variable lengths be arranged in a raster and that the remaining code words be distributed in the remaining gaps, so that the start of a code word which is arranged at a raster point can be more easily found without full decoding or in the case of an incorrect transmission.

It is true that the known method provides some remedy for error propagation by means of rearranging the code words. For some code words, a fixed location in the bit stream is agreed upon, whereas the remaining gaps are available for the remaining code words. This does not cost any additional bits, but prevents, in the case of an error, error propagation among the rearranged code words.

German Patent Application 19 747 119.6-31, which was published after the filing date of the present application, proposes that not just any code words be located at raster points, but that code words which are significant from a psycho-acoustic point of view, i.e. code words for spectral values which make a significant contribution to the audio signal, be located at raster points. A data stream with code words of variable lengths, such as is produced by such an encoder, is shown in Fig. 5. As in Fig. 6, the data stream also includes 10 code words, with the priority code words being shaded. The first priority code word is located such as to start at a first rater point 100, the second priority code word is located such as to start at a second raster point 101, the third priority code word is located such as to start at a third raster point 102, the fourth

priority code word is located such as to start at a fourth raster point 103 and the fifth priority code word is located such as to start at a fifth raster point 104. A first segment 105 is defined by the raster points 100 and 101. Similarly, a second 106, a third 107, a fourth 108 and a final segment 109 are defined. It is shown in Fig. 5 that the first two segments 105 and 106 have a different length from the two segments 107 and 108 and yet a different length from the final segment 109. Non-priority code words 6, 7, 8, 9 and 10 are then entered in the data stream following the priority code words such that the latter is filled up, so to speak. As is shown in Fig. 5, in the post-published method, the non-priority code words are consecutively inserted in the raster after the priority code words have been written. Specifically, the non-priority code word No. 6 is entered following the non-priority code word 1. The space still remaining in the segment 105 is filled up with the following non-priority code word 7, with the remainder of the non-priority code word 7, i.e. 7b, being written in the next free space, i.e. in the segment 107, directly following the priority code word 3. The same procedure is followed for the non-priority code words 8 to 10.

The advantage of the post-published method illustrated in Fig. 5 is that the priority code words 1 to 5 are protected against error propagation, since their starting points coincide with raster points and are therefore known.

In case, for example, the priority code word 2 has been damaged in transmission, it is very likely in the prior art shown in Fig. 6 that a decoder will not be able to decode any of the remaining code words 3 to 10 correctly. In the method shown in Fig. 5, however, the next code word, i.e. priority code word 3, starts at the raster point 102 such that the decoder will, at any rate, find the correct start of code word 3. Therefore, in the method shown in Fig. 5, no sequence error whatsoever will occur, and only priority

code word No. 2 will be damaged. Consequently, this method provides effective protection for priority code words which are located at raster points.

However, there is no effective protection for non-priority code words. Referring to Fig. 5, damaging the non-priority code word No. 6 such that the decoder assumes, as an incorrect code word No. 6, a code word which is one bit shorter, will result in the fact that it is also no longer possible to correctly decode code word No. 7, since the last bit of the correct code word No. 6 is interpreted as being the start of the next code word No. 7. Therefore, an error in code word No. 6 will lead to the fact that, at a very high probability, it will no longer be possible, due to a sequence error, to correctly decode any code words following it even in case they have not been adversely affected by a transmission error.

DE 691 26 565 T2 relates to a method for transmitting codes of variable lengths. By this method, a data stream is produced in which, starting from the start of the data stream, code words of variable lengths are written in a first direction up to a certain point in the data stream. However, in order to increase error robustness, not the entire data stream is written in one direction, but merely up to the predetermined point. From the end of the data stream, the remainder of the code words of variable lengths is then written in an opposite direction of writing up to the predetermined point, so that a data stream results whose first half comprises code words which are written in the forward direction and whose second half comprises code words which are written in the backward direction.

US Patent No. 5,852,469 relates to encoding and decoding systems for code words with variable lengths and code words with specified lengths. It is provided, for code words with specified lengths, to provide synchronous positions in the data stream whose distance is equal to the length of the

code words of specified lengths. The code words are then entered into the data stream such that they all start at a synchronous position. For code words of variable lengths, a data stream with a start and an end, however without synchronous positions, is provided in order to enter code words of variable lengths in the forward direction, starting from the start of the data stream up to a certain position behind the center of the data stream. Starting from the end of the data stream up to the predetermined position in the center, code words of variable lengths are then entered in the opposite direction of writing.

Summary of the Invention

It is the object of the present invention to render code words of variable lengths more error-robust.

In accordance with a first aspect of the present invention, this object is achieved by an apparatus for producing a data stream, which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths which are divided up into a plurality of sets of code words, the apparatus comprising: a first device for writing at least a part of each code word of a first set of code words into the data stream in a first direction of writing, starting at a first raster point of a segment, respectively; a second device for writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing, which is opposite to the first direction of writing, starting from a second raster point, respectively, the code words of the second set being assigned to segments in accordance with a predetermined assignment rule, such that each code word of the second set is assigned to a different segment, wherein, in case that a code word of the

second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment, in accordance with a predetermined rule, by the first device or the second device, after the second device for writing has processed all remaining segments with the other code words of the second set.

In accordance with a second aspect of the present invention, this object is achieved by an apparatus for reading a data stream which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, wherein the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set being assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined rule, the apparatus comprising the following: a first apparatus for reading in a first direction of reading which corresponds to the first direction of writing; a second device for reading in a second direction of reading which is opposite to the first direction of reading; and a control device for supplying the code words of the first set to the first reading device, each code word of the first set starting at the first raster point of a segment, and for supplying the code words of the second set to the second reading device, wherein one jumps to the second raster point of a segment in accordance with the predetermined assignment rule, and wherein, after all segments have been searched for code words of the second set and at least one code word of the second set is not present or not complete, one jumps at least to one further

segment in accordance with the predetermined rule in order to obtain the at least one code word of the second set completely or a part of the at least one code word.

In accordance with a third aspect of the present invention, this object is achieved by a method for producing a data stream, which comprises a multitude of raster points (41 - 47) as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths, which are divided up into a plurality of sets of code words, the method comprising the following steps: writing at least a part of each code word of a first set of code words into the data stream in a first direction of writing, starting from a first raster point of a segment, respectively; writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing which is opposite to the first direction of writing, starting from a second raster point of a segment, respectively, the code words of the second set being assigned to segments in accordance with the predetermined assignment rule, such that each code word of the second set is assigned to a different segment, wherein, in case a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment in the first or second direction of writing, in accordance with a predetermined regulation, after all remaining segments have been processed with the other code words of the second set.

In accordance with a fourth aspect of the present invention, this object is achieved by a method for reading a data stream which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, in which method the data stream comprises a plurality of sets of

code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set is assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined regulation, the method comprising the following steps: reading the code words of the first set, starting from a first raster point of a segment, in a first direction of reading which corresponds to the first direction of writing; reading the code words of the second set, starting from a second raster point of a segment, in a second direction of reading which is opposite to the first direction of reading wherein it is jumped, for reading the code words of the second set, to the second raster point of a segment in accordance with the predetermined assignment rule, wherein, after all segments have been searched for code words of the second set or at least a code word of the second set is not present or not completely present, one jumps to at least one further segment in accordance with the predetermined rule so as to obtain the at least one code word of the second set completely or a part of the at least one code word.

The present invention is based on the realization that the robustness of a data stream toward transmission errors and, in particular, toward sequence errors with code words of variable lengths can be decisively increased when the data stream is not written only in one direction of writing but is written, additionally, in the other direction of writing. In the most general case, a data stream will always have a start and an end. In the prior art, in the simplest case, the data stream was written onto, starting from the starting point, until it was completed. Thereby it was possible that a transmission error in the first code word could result in that the entire data stream could no

longer be decoded correctly, even if all other code words were transmitted correctly. In accordance with the invention, such a data stream may be written such that the first half of the data stream is written starting from the start of the data stream, whereas the second half of the data stream is written starting from the end of the data stream. Even from this simple example, it can be seen that a transmission error in the first half of the data stream no longer has the effect that code words of the second data stream can also no longer be decoded correctly due to sequence errors. This is the case because the decoder knows that after half of the data stream it must continue reading starting from the end of the data stream, to be precise in the opposite direction of reading. Thus, a certain error robustness is obtained merely due to reversing the direction of writing/the direction of reading with virtually no extra effort.

As has already been mentioned, code words with variable lengths are written into a data stream using raster points such that a decoder can decode with a limited number of sequence errors since, by definition, certain code words start at raster points. For maximum error robustness, it will, in principle, be desirable to have a raster which is as narrow as possible, such that a decoder can find the correct starting points of as many code words as possible. On the other hand, an increase in the number of raster points, i.e. a reduction of the segment length, will result in that fewer and fewer code words which, as is known, have variable lengths, completely fit into the raster, which is why measures are taken for the end sections of the same to be written into other segments in order to be able to be detected correctly in decoding. This leads to an increasing additional effort with a raising number of raster points and with a reduction in the segment length.

In the prior art, code words were written merely in one single direction of writing, starting from a raster point,

as has been explained with reference to Figures 5 and 6. In accordance with the invention, code words are now also written in the opposite direction of writing, starting from raster points, which causes the number of the code words which can be written starting at raster points to double, in the best case, essentially without any additional effort. By writing the data stream by means of a device for writing in a first direction of writing starting from a reference point and by means of a second device for writing in a second direction of writing which is opposite to the first direction of writing, starting from a different reference point, it becomes possible to not only utilize "one side" of a reference point, but both sides of a reference point for error robustness, i.e. for protection against propagation or sequence errors. Depending on the form of implementation, every other code word can be written in the same direction, for example, and every remaining code word can be written in the other direction. On the other hand, the code words of variable lengths can be divided up into different sets of code words, for example in accordance with their priority, such that, for example, all code words of the first set are written in the first direction of writing, starting at raster points, and all code words of the second set can be written in the second direction of writing, starting at raster points.

In addition, remainders of code words may be written in the same direction of writing as the starting sections of the code words or, alternatively, in the opposite direction of writing. It is evident that measures must be taken in order for a decoder, i.e. an apparatus for reading the data stream, to always be fully aware of which direction of writing has been used in writing. This may either be specifically set or be transmitted as side information to the data stream of code words of variable lengths. The same applies also to the segment lengths, wherein the segment length may either be equal or vary over the entire data stream, wherein the current segment length can of course

also be specifically set in a decoder or can be transmitted via side information together with the code words of variable lengths.

Brief Description of the Drawings

Preferred embodiments of the present invention will be explained in detail below with reference to the attached drawings, in which:

Fig. 1 shows an inventive apparatus for writing an error-robust data stream;

Fig. 2 shows an inventive apparatus for reading an error-robust data stream;

Fig. 3 shows a procedural diagram of the inventive method by means of three sets of code words of variable lengths;

Fig. 4 shows a procedural diagram for illustrating the inventive method for reading a data stream which has been produced in accordance with Fig. 3;

Fig. 5 shows a data stream which is produced by a known apparatus and in which the priority code words are exposed to error propagation;

Fig. 6 shows a data stream in which sorting by priority code words and non-priority code words has been carried out.

Detailed Description of preferred Embodiments

Before Fig. 1 will be described in more detail, it should be noted that encoding with code words of variable lengths is also referred to as entropy encoding in the art. One

representative example of entropy encoding is the so-called Huffman encoding. In principle, in Huffman encoding, the information symbols to be encoded are statistically examined in order to determine shorter code words for the information symbols occurring more frequently than for information symbols occurring less frequently. In a complete Huffman code, all code words are terminated ends or branches of a code tree. For example, a Huffman decoder serially reads in a data stream with Huffman code words and, put graphically, jumps to a branching of the specified code tree with each bit that it reads in additionally until, after a certain number of jumps, which corresponds to the number of bits of the code word, i.e. to the length of the code word, it arrives at a branch end which does not have any further branching and is therefore a code word. The decoder then knows that a new code word starts with the next bit. This process is repeated as often as required until the data stream has been completely read in. With each time that the Huffman encoder jumps back to the starting point, i.e. to the root of the tree, a code word is present at its point of origin. Since the lengths of the code words are implicitly specified by the code words themselves or by the code tree known in the encoder and in the decoder, it can be seen that an interference in the data stream which leads to a reversal of a bit misleads the decoder in the code tree, so to speak such that it ends up with a different code word, i.e. an incorrect code word, which is very likely to have a different length from the correct code word. In this case, the decoder will, once it has arrived at the incorrect code word, jump back and, due to the bits then following, again move from one branching point to another in the code tree. However, it is not possible for the decoder to avoid a sequence error, unless it coincidentally ends up on the "correct track".

Therefore, error protection, as is provided by the present invention, must be performed in order to ensure error-robust transmission. The apparatus for producing a data

stream of code words of variable lengths in accordance with the present invention may therefore act as a sending or output stage of a Huffman encoder, as it were, whereas the apparatus for reading a data stream of code words of variable lengths may act as a receiving or input stage of a Huffman encoder. It can be seen from this that the present invention is not only applicable to Huffman encoders, but to any code having code words of variable lengths which is susceptible to sequence errors.

Figure 1 shows an apparatus 10 in accordance with the invention for producing an error-robust data stream at an output 12, when code words of variable lengths are input into the apparatus 10 at an input 14. The apparatus includes a first device 16 for writing in a first direction of writing, starting from a first reference point, and a second device 18 for writing in a second direction of writing, starting from a second reference point. Depending on the complexity of the apparatus 10, the code words of variable lengths may both be applied to both devices 16 and 18 for writing, as is illustrated in Figure 1 by a simple branching point 20 and a corresponding combination point 22. The selection as to which code words are written in which direction, and/or as to which sections of code words are written in which direction, would then be made by devices 16 and 18. Instead of the node 20, a demultiplexer may be present alternatively, which supplies certain code words, for example code words of a set of code words, to the first device 16, and supplies certain code words to the second device 18. By analogy therewith, the combination point 22 would then be implemented by a multiplexer multiplexing the error-robust data stream 12. Other devices, which would be controlled correspondingly, for supplying the two devices 16 and 18 with the code words of variable lengths are apparent for those skilled in the art in view of the present description.

An apparatus 30 for reading an error-robust data stream, which apparatus is complementary to the apparatus 10 for producing a data stream, shown in Figure 1, is shown in Figure 2. Apparatus 30 includes an input 32, where the error-robust data stream is entered after transmission via a radio link for example, in order to obtain, again, at a starting point 34, the code words of variable lengths which have been fed into the input 14 of the apparatus 10 in Figure 1. Apparatus 30 for reading the data stream includes a first device 36 for reading in the first direction, starting from the first reference point, and a second device 38 for reading the data stream in the second direction, starting from a second reference point.

It is evident that apparatus 30 also contains a branching point 40 and a combination point 42, the feeding-in of the error-robust data stream into the two devices 36 and 38 taking place, for example, based on a specifically set algorithm or based on side information which may also be transmitted, together with the error-robust data stream, from the sender, i.e. the apparatus 10 in Figure 1, to the receiver, i.e. the apparatus 30 in Figure 2.

Fig. 3 illustrates, by means of an example, the inventive method for writing code words of variable lengths. In the example, there are 15 code words of variable lengths 30 which are preferably divided up into a first set having 6 code words 1 to 6, into a second set also having 6 code words 7 to 12 and into a third set having the remaining 3 code words 13 to 15. As is shown in Fig. 3, code words 30 have variable lengths.

In accordance with a preferred embodiment of the present invention, the segment length, i.e. the length of the segment, is longer than the length of the longest code word of the first set. The code words of the first set are arranged at raster points 41 to 46, wherein, for the last segment No. 6, a raster point is indicated by a dotted

line, which raster point is not used, however, since the end 47 of the data stream can also be considered as a raster point as it were and since the raster point indicated by a dotted line is thus superfluous. The first segment No. 6 is therefore longer than the other segments, which is completely irrelevant for the present invention, however. Generally speaking, the segments may have any lengths, which change within the data stream, it being understood that the current length of a segment must be known to the decoder so that the inventive advantages can be utilized.

Firstly, the code words of the first set are written into the data stream in a step a), which results in a fragmentary data stream indicated by 31, in which the code words of the first set are written into a respective segment from left to right, as is indicated by arrows 48 which are to symbolize the direction of writing in the entire Fig. 3. Since the segment length is selected to be longer than the longest length of a code word of the first set, only one single attempt is needed for step a). In case the segments are shorter, more attempts may be required accordingly.

Now the code words of the second set are written into the data stream 31 in a step b). In order to achieve high error robustness, the code words of the second set are not written from left to right like the code words of the first set, but are written from right to left, starting from the second raster point, respectively, e.g. the raster point 42 for the first segment, as is indicated by the respective arrow of writing direction. The writing of the code words of the second set takes place in accordance with a predetermined assignment rule which says, in the example selected, that the first code word of the second set is to be written in the same segment as the first code word of the first set, however always on the condition that there is still room in this segment. The data stream 32 resulting

from the first attempt shows that in the first segment there was only so much room for writing the starting section of code word No. 7.

In contrast to the prior art, where the second part of code word No. 7 would have been written into the second segment, the second half of code word No. 7, i.e. 7 b), is stored for writing it into the data stream in a second attempt in accordance with a predetermined regulation, i.e. in accordance with an regulation which must also be known to the decoder. Fig. 3 clearly shows that in the second segment, there was still enough room between code word Nos. 2 and 8 for the final section of code word No. 7 to be entered. In case there had not been enough room, the third section of the code word would have been entered into segment No. 3. Thus, in Fig. 3, the predetermined regulation for entering code word No. 7 into the data stream consists in proceeding by one segment in each case. Of course, one may also proceed by two segments or by three or more, such that, as a consequence, the second segment 7 b) could then be written, instead of the second segment, into the third, into the fifth in the next attempt, etc. The order of segments which is used to accommodate the second part of section 7 somewhere is arbitrary. However, it must be transparent to the decoder so that the re-sorted data stream can be re-read.

The code words of the third set 13 to 15 are now to be entered into the resulting data stream 33, which is also still fragmentary. By analogy with step b), this is done preferably by the same assignment rule such that the first code word of the third set is assigned to the first segment, that the second code word of the third set is assigned to the second segment, that the third code word of the third set is assigned to the third segment, etc. This assignment rule is entirely arbitrary for the third set and may also be different from the assignment rule for the second set, with each code word of a set being assigned to

a different segment in accordance with the invention. Similarly, the direction of writing can also be selected arbitrarily for each set. Preferably, an alternating writing direction order is used. Alternatively, however, it is also possible to write two adjacent sets using the same direction of writing. In principle, the writing direction may also altered within a set.

The first attempt in step c) was successful only in that the first section of code word No. 15 was entered, resulting in a fragmentary data stream 34. Code words 13, 14 and the second section of code word 15, i.e. 15 b) are stored for being accommodated in the second, third, fourth, fifth and sixth attempts, wherein the second section 15b could be accommodated in the fourth segment in the second attempt (data stream 35), wherein nothing could be accommodated in the third attempt, wherein the starting section of code word 14 could be accommodated in the fourth attempt (data stream 36), wherein the final section of code word 14, i.e. 14b could be accommodated in the fifth attempt (data stream 37) and wherein, finally, the first code word of the third set could be entered in the sixth segment in the sixth and final attempt, which results in the error-robust data stream 38 for the example illustrated here. The method described using Fig. 3 ensures that the length of the error-robust data stream exactly corresponds to the sum of the lengths of the code words of variable lengths, which is self-evident for the purposes of entropy encoding for data reduction. However, the present invention is not limited to the error-robust data stream having the minimal length, since error robustness is not affected by any filler bits that may be present.

When looking at the robust data stream shown in Fig. 3, it can be seen that the start of code word No. 8, i.e. raster point 43, is entirely independent of the end of code word No. 7. Moreover, the start of code word No. 9, i.e. raster point 44, is entirely independent of the end of code word

No. 8. Additionally, it should be noted that due to the opposite writing order, a data error in code word No. 1 in the first segment, for example, which leads to the fact that the incorrect code word is one bit shorter than the correct code word No. 1 due to the data error, does not lead to a destruction of the starting section of code word No. 7a, since the latter was written from right to left instead of from left to right. In case it had been written from left to right, a decoder would take the remaining bit from the initially correct code word No. 1 as the starting bit of code word No. 7, which would result in a sequence error from 1 to 7. However, this sequence error would not propagate to 8, since code word No. 8, again, is entirely independent of code word No. 7, since the writing order was chosen to be from right to left. In case the writing order of code word No. 8 is equal to the writing order of the code words of the first set, the error would not propagate from 7 to 8 either, since code word No. 8 would be written adjacent to code word No. 2 before the second part 7b due to the assignment rule and is, therefore, not influenced by an incorrect section 7b.

By means of an appropriate example, Fig. 4 shows the operation of the apparatus for reading the error-robust data stream 38. Initially, the code words of the first set are extracted from the error-robust data stream in step a). For this purpose, the inventive apparatus, which may be coupled to a Huffman decoder, reads the code word of the first set starting from the first raster point 41, reads code word No. 2 of the first set starting from the second raster point 42, etc., until all code words 1 to 6 of the first set have been read in. It is self-evident that the apparatus for reading the data stream selects the same direction as has been used by the apparatus for producing.

Subsequently, the code words of the second set are extracted from the remaining data stream 50 in step b). Here, the decoder jumps to the second raster point 42 of

the first segment and obtains the starting section of code word 7 of the second set (the first segment is now empty), whereupon it does not read in the second section 7b, but 7a is first stored in order to then read in the second code word of the second set starting from the second raster point of the second segment, etc. The result is a residual data stream 51 in which the first segment has been completely emptied. Since the decoder does not now read the code word 7 continuously, but always reads segment by segment on the basis of the assignment rule used for the apparatus for producing the data stream, the error robustness which has already been described and which strongly reduces propagation of sequence errors is ensured.

In a second attempt for extracting the code words of the second set, the second part of code word 7b is now read in the second segment in accordance with the existing writing direction, whereupon only code words of the third set remain in the resulting data stream 52, and the second segment is empty. These are extracted in step c), wherein the starting section of code word 15 has been initially determined in a first attempt, which is not stored however, since code word 15 has not been found complete in the third segment. The third segment is now empty. In a second attempt, code word 15 can be found complete. However, the search for code word 14 in segment 3 and for code word 15 in segment 14 remained without success, which can be seen by the data stream 54. Nevertheless, in the fourth attempt, the search for code word 14 in the fifth segment lead to a positive result. However, code word 14 was not complete, which is why the starting section 14a was stored in order to examine the remaining data stream 55 in a fifth attempt and to fully read in, in a final sixth attempt, data stream 56, which now only consists of the sixth segment and of code word 13.

Even though in the previous example merely a division of code words into a starting section and a final section was

illustrated by way of example, any type of division is possible in principle. Error-robust decoding will be ensured as long as the decoder observes the assignment of code words of the second set or of the third set and of further sets to different segments, respectively. Moreover, it is obvious that the sorting of the final sections of code words into the data stream is arbitrary as long as the decoder or the read-in circuit upstream of the decoder knows exactly which predetermined regulation has been carried out in the encoder.

In order to once again underline the advantages and/or the operation of the present invention, reference is made to the error-robust data stream No. 38 of Figure 3. When looking at the first segment between the raster points 41 and 42, it can be seen that code word No. 1 is written from left to right, starting from the first raster point 41, as is clearly indicated by the arrow drawn underneath. The first part of code word No. 7, i.e. 7a, however, is written from right to left, starting from the second raster point 42. If both code words No. 1 and No. 7 or 7a were written into the data stream only from left to right, the start of code word 7 or the starting point of the starting section 7a of code word 7 would depend on the end of code word 1. Therefore, a transmission error in code word 1 would almost inevitably also lead to a sequence error in code word 7. However, if code word 7 is written in the opposite direction of writing, starting from the second raster point 42, in accordance with the invention, the starting point of code word 7 or of starting section 7a of code word 7 no longer depends on code word 1 but is determined by the raster or raster point 42. A decoder will always know this starting point, which is why an error in code word 1 will not lead to an error in code word 7. It can be seen from the error-robust data stream 38 of Figure 3 that the first section 7a and the second section 7b of code word No. 7 are both written in the same direction of writing. However, this is not compulsory. Of course, the second section 7b of

code word 7 may also be written from left to right and would then start at the end of the second code word No. 2.

If the raster points are chosen such that the segment lengths are longer than the longest length of a code word of the first set, no segment will be filled in completely by the code word of the first set, as can be seen, for example, from the data stream 31 of Figure 3. In this case, the number of code words which can be written starting at raster points is actually doubled without there being any need of providing one single additional raster point.

Claims

1. Apparatus for producing a data stream, which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths which are divided up into a plurality of sets of code words, the apparatus comprising:

a first device for writing at least a part of each code word of a first set of code words into the data stream in a first direction of writing, starting at a first raster point of a segment, respectively;

a second device for writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing, which is opposite to the first direction of writing, starting from a second raster point, respectively, the code words of the second set being assigned to segments in accordance with a predetermined assignment rule, such that each code word of the second set is assigned to a different segment,

wherein, in case that a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment, in accordance with a predetermined rule, by the first device or the second device, after the second device for writing has processed all remaining segments with the other code words of the second set.

2. Apparatus as claimed in claim 1, wherein the first writing device is arranged so as to write a starting section of a code word, and wherein the second writing device is arranged so as to write at least a part of the remainder of the same code word.

3. Apparatus as claimed in claim 1, wherein the data stream comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, the first writing device being arranged so as to write a starting section of a first code word at a first raster point of a first segment and to write a starting section of a second code word at a first raster point of a following segment, and the second writing device being arranged so as to write at least a part of the remainder of the first code word starting from the second raster point of the second segment and to write the remainder of the second code word starting from the second raster point of a further segment, respectively.

4. Apparatus as claimed in claim 1, wherein the second writing device is arranged so as to write starting from the second raster point of the segment into which the first writing device has written, wherein, if the respective code word of the second set is longer than a vacant space in the segment, the part of the code word of the second set which fits into the vacant space is written into the segment, and the remainder is initially stored.

5. Apparatus as claimed in claim 1, wherein the second writing device is arranged so as to become active only once all code words of the first set have been written into the data stream.

6. Apparatus as claimed in claim 4, wherein the second writing device is arranged so as to write at least a part of the remainder of the code word of the second set into the data stream, starting from the end of a different code word of the second set.

7. Apparatus as claimed in claim 1, wherein the code words are divided up into at least three sets, the first writing device being arranged so as to write the code words of the first set starting from first raster points of segments, the second writing device being arranged so as to write the code words of the second set starting from the other raster points of the segments, the first or second writing device further being arranged so as to write the third set starting from ends of the code words of the first and the second set, respectively.

8. Apparatus as claimed in claim 7, wherein the first or the second writing device is further arranged so as to write the third set starting from ends of the code words of the first and second set, respectively, in accordance with a predetermined assignment rule, such that each code word of the third set is assigned to a different segment.

9. Apparatus for reading a data stream which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, wherein the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such

that each code word of a set being assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined rule, the apparatus comprising the following:

a first apparatus for reading in a first direction of reading which corresponds to the first direction of writing;

a second device for reading in a second direction of reading which is opposite to the first direction of reading; and

a control device

for supplying the code words of the first set to the first reading device, each code word of the first set starting at the first raster point of a segment, and

for supplying the code words of the second set to the second reading device, wherein one jumps to the second raster point of a segment in accordance with the predetermined assignment rule, and

wherein, after all segments have been searched for code words of the second set and at least one code word of the second set is not present or not complete, one jumps at least to one further segment in accordance with the predetermined rule in order to obtain the at least one code word of the second set completely or a part of the at least one code word.

10. Apparatus as claimed in claim 9, wherein, if only one starting section of a code word is read by a

writing device in one segment, this starting section is stored.

11 Apparatus as claimed in claim 9, wherein the code words are Huffman code words.

12. Apparatus as claimed in claim 9, wherein the code words represent information symbols and wherein code words of the first set represent more significant information symbols than code words of the second set or of further sets.

13. Apparatus as claimed in claim 12, wherein the information symbols are spectral values of an audio signal, and wherein the code words of the first set are spectral values which are significant from a psycho-acoustic point of view and which are to be protected from error propagation due to a transmission error in the data stream.

14. Method for producing a data stream, which comprises a multitude of raster points (41 - 47) as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths, which are divided up into a plurality of sets of code words, the method comprising the following steps:

writing at least a part of each code word of a first set of code words into the data stream in a first direction of writing, starting from a first raster point of a segment, respectively;

writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing which is opposite to the first direction of writing, starting from a second raster point of a segment, respectively, the code words of

the second set being assigned to segments in accordance with the predetermined assignment rule, such that each code word of the second set is assigned to a different segment, wherein, in case a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment in the first or second direction of writing, in accordance with a predetermined regulation, after all remaining segments have been processed with the other code words of the second set.

15. Method for reading a data stream which comprisesa multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, in which method the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set is assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined regulation, the method comprising the following steps:

reading the code words of the first set, starting from a first raster point of a segment, in a first direction of reading which corresponds to the first direction of writing;

reading the code words of the second set, starting from a second raster point of a segment, in a second direction of reading which is opposite to the first direction of reading wherein it is jumped, for reading

the code words of the second set, to the second raster point of a segment in accordance with the predetermined assignment rule, wherein, after all segments have been searched for code words of the second set or at least a code word of the second set is not present or not completely present, one jumps to at least one further segment in accordance with the predetermined rule so as to obtain the at least one code word of the second set completely or a part of the at least one code word.

Apparatus and Method for Producing a Data Stream and Apparatus and Method for Reading a Data Stream

Abstract

An entropy encoder includes an apparatus for producing a data stream which comprises two reference points, of code words of variable lengths, the apparatus comprising a first device for writing at least a part of a code word into the data stream in a first direction of writing, starting from a first reference point, and a second device for writing at least a part of a code word into the data stream in a second direction of writing, which is opposite to the first direction of writing, starting from the other reference point. In particular, when a raster having a plurality of segments is used to write the code words of variable lengths into the data stream, the number of the code words which can be written starting at raster points is doubled, in the best case, such that the data stream of code words of variable lengths is robust toward a propagation of sequence errors.

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Apparatus and Method for Producing a Data stream and Apparatus and Method for Reading a Data stream

[Description]

Field of the Invention

The present invention relates to encoding with code words of variable lengths and, in particular, to producing and reading data streams with code words of variable lengths, which are robust with regard to errors in transmission.

Background of the Invention and Prior Art

Modern audio encoding or decoding methods which work by the MPEG layer 3 standard, for example, are capable of compressing the data rate of audio signals, e.g. by a factor 12, without noticeably degrading the quality thereof. In order to achieve such a high data rate reduction, an audio signal is sampled, whereby a sequence of discrete-time samples is obtained. As is known in the art, the sequence of discrete-time samples is windowed in order to obtain windowed blocks of time samples. A block of time-windowed samples is then transformed to the frequency range by means of a filter bank, a modified discrete cosine transform (MDCT) or other suitable device, in order to obtain spectral values which, as a whole, represent the audio signal, i.e. the time section determined by the block of discrete-time samples, in the frequency range. Usually, time blocks which overlap at 50% are produced and transformed to the frequency range by means of a MDCT whereby, due to the specific properties of the MDCT, 1024 discrete-time samples, for example, always lead to 1024 spectral values.

It is known that the receptivity of the human ear depends on the momentary spectrum of the audio signal itself. This

dependency is covered in the so-called psycho-acoustic model by means of which it has been possible for quite some time to calculate masking thresholds depending on the momentary spectrum. Masking means that a specific tone or a spectral component is hidden in case an adjacent spectral range, for example, has relatively high energy. This fact of masking is utilized in order to quantize as closely as possible the spectral values present after the transformation. The aim is therefore to avoid audible interferences in the re-decoded audio signal on the one hand and to use as few bits as possible on the other hand in order to encode or, in this case, to quantize the audio signal. The interferences introduced by quantization, i.e. quantization noise, are intended to be below the masking threshold and, therefore, to be inaudible. In accordance with known methods, a classification of the spectral values in so-called scale factor bands is carried out, which should correspond to the critical bands, i.e. frequency groups, of the human ear. Spectral values in a scale factor group are multiplied by a scale factor in order to carry out overall scaling of spectral values of a scale factor band. The scale factor bands scaled by the scale factor are then quantized, whereupon quantized spectral values are produced. It is understood that grouping in scale factor bands is not critical. However, it is used in the MPEG layer 3 standards or in the MPEG 2 AAC standard (AAC = advanced audio coding).

A very essential aspect of data reduction lies in entropy encoding of the quantized spectral values, which follows quantizing. Huffman encoding is usually used for entropy encoding. A Huffman coding is understood to mean a coding with a variable length, i.e. the length of the code word for a value to be encoded is dependent on the probability of occurrence thereof. Logically, the most probable character is assigned the shortest code, i.e. the shortest code word, so that very good redundancy reduction can be achieved by means of Huffman encoding. An example for a

generally-known coding with a general length is the Morse code.

In the field of audio encoding, Huffman codes are used for encoding the quantized spectral values. A modern audio encoder, which works, for example, in accordance with the MPEG 2 AAC standard, uses different Huffman code tables for encoding the quantized spectral values, which Huffman code tables are assigned to the spectrum by certain criteria on a section-by-section basis. In this process, 2 or 4 spectral values are always encoded together in one code word.

One difference between the method in accordance with MPEG 2 AAC and the method in accordance with MPEG layer 3 is that different scale factor bands, i.e. different spectral values, are grouped into any number of spectral sections. With AAC, one spectral section includes at least four spectral values, but preferably more than four spectral values. The entire frequency range of the spectral values is therefore divided up into adjacent sections, with one section representing one frequency band such that all sections together cover the entire frequency range, which is superimposed by the spectral values after the transformation thereof.

As in the MPEG layer 3 method, one section is assigned to a so-called "Huffman table" from a plurality of such tables in order to achieve a maximum redundancy reduction. In the bit stream of the AAC method, which usually comprises 1024 spectral values, are now the Huffman code words for the spectral values in an ascending order of frequencies. The information on the table used in each frequency section is transferred in the side information. This situation is shown in Fig. 6.

Fig. 6 shows the exemplary case where the bit stream includes 10 Huffman code words. In case one code word is

always formed from one spectral value, 10 spectral values may be encoded here. However, usually 2 or 4 spectral values are always jointly encoded by one code word, which is why Fig. 6 shows a part of the encoded bit stream which includes 20 or 40 spectral values. In the case where each Huffman code word includes 2 spectral values, the code word designated by No. 1 represents the first two spectral values, with the length of code word No. 1 being relatively short, which means that the values of the first two spectral values, i.e. of the two smallest frequency coefficients, occur relatively frequently. The code word bearing the No. 2, however, has a relatively long length, which means that the amounts of the 3rd and 4th spectral coefficients in the encoded audio signal are relatively rare, which is why they are encoded with a relatively large amount of bits. Further, it is apparent from Fig. 6 that the code words with the numbers 3, 4 and 5, which represent the spectral coefficients 5 and 6 or 7 and 8 or 9 and 10, also occur relatively frequently, since the length of the individual code words is relatively small. The same applies to the code words bearing the numbers 6 to 10.

As has already been mentioned, it is clearly apparent from Fig. 6 that the Huffman code words for the encoded spectral values are arranged in the bit stream in a linearly ascending manner with regard to the frequency in case a bit stream which is produced by a known encoding apparatus is considered.

One major drawback with regard to Huffman codes, in the case of faulty channels, is error propagation. It may be assumed, for example, that code word No. 2 in Fig. 6 is interfered with. There is a certain, not low, probability that the length of this wrong code word No. 2 is also modified. It therefore is different from the correct length. In case, in the example of Fig. 6, code word No. 2 has been modified in its length due to an interference, it is no longer possible for an encoder to determine the

starts of the code words 3 to 10, i.e. of almost the entire audio signal represented. This means that all other code words following the code word which has been interfered with can no longer be correctly encoded, since it is not known where these code words start, and since an incorrect starting point was selected due to the error.

As a solution to the problem of error propagation, European Patent No. 0 612 156 proposes that a part of the code words of variable lengths be arranged in a raster and that the remaining code words be distributed in the remaining gaps, so that the start of a code word which is arranged at a raster point can be more easily found without full decoding or in the case of an incorrect transmission.

It is true that the known method provides some remedy for error propagation by means of rearranging the code words. For some code words, a fixed location in the bit stream is agreed upon, whereas the remaining gaps are available for the remaining code words. This does not cost any additional bits, but prevents, in the case of an error, error propagation among the rearranged code words.

German Patent Application 19 747 119.6-31, which was published after the filing date of the present application, proposes that not just any code words be located at raster points, but that code words which are significant from a psycho-acoustic point of view, i.e. code words for spectral values which make a significant contribution to the audio signal, be located at raster points. A data stream with code words of variable lengths, such as is produced by such an encoder, is shown in Fig. 5. As in Fig. 6, the data stream also includes 10 code words, with the priority code words being shaded. The first priority code word is located such as to start at a first rater point 100, the second priority code word is located such as to start at a second raster point 101, the third priority code word is located such as to start at a third raster point 102, the fourth

priority code word is located such as to start at a fourth raster point 103 and the fifth priority code word is located such as to start at a fifth raster point 104. A first segment 105 is defined by the raster points 100 and 101. Similarly, a second 106, a third 107, a fourth 108 and a final segment 109 are defined. It is shown in Fig. 5 that the first two segments 105 and 106 have a different length from the two segments 107 and 108 and yet a different length from the final segment 109. Non-priority code words 6, 7, 8, 9 and 10 are then entered in the data stream following the priority code words such that the latter is filled up, so to speak. As is shown in Fig. 5, in the post-published method, the non-priority code words are consecutively inserted in the raster after the priority code words have been written. Specifically, the non-priority code word No. 6 is entered following the non-priority code word 1. The space still remaining in the segment 105 is filled up with the following non-priority code word 7, with the remainder of the non-priority code word 7, i.e. 7b, being written in the next free space, i.e. in the segment 107, directly following the priority code word 3. The same procedure is followed for the non-priority code words 8 to 10.

The advantage of the post-published method illustrated in Fig. 5 is that the priority code words 1 to 5 are protected against error propagation, since their starting points coincide with raster points and are therefore known.

In case, for example, the priority code word 2 has been damaged in transmission, it is very likely in the prior art shown in Fig. 6 that a decoder will not be able to decode any of the remaining code words 3 to 10 correctly. In the method shown in Fig. 5, however, the next code word, i.e. priority code word 3, starts at the raster point 102 such that the decoder will, at any rate, find the correct start of code word 3. Therefore, in the method shown in Fig. 5, no sequence error whatsoever will occur, and only priority

code word No. 2 will be damaged. Consequently, this method provides effective protection for priority code words which are located at raster points.

However, there is no effective protection for non-priority code words. Referring to Fig. 5, damaging the non-priority code word No. 6 such that the decoder assumes, as an incorrect code word No. 6, a code word which is one bit shorter, will result in the fact that it is also no longer possible to correctly decode code word No. 7, since the last bit of the correct code word No. 6 is interpreted as being the start of the next code word No. 7. Therefore, an error in code word No. 6 will lead to the fact that, at a very high probability, it will no longer be possible, due to a sequence error, to correctly decode any code words following it even in case they have not been adversely affected by a transmission error.

DE 691 26 565 T2 relates to a method for transmitting codes of variable lengths. By this method, a data stream is produced in which, starting from the start of the data stream, code words of variable lengths are written in a first direction up to a certain point in the data stream. However, in order to increase error robustness, not the entire data stream is written in one direction, but merely up to the predetermined point. From the end of the data stream, the remainder of the code words of variable lengths is then written in an opposite direction of writing up to the predetermined point, so that a data stream results whose first half comprises code words which are written in the forward direction and whose second half comprises code words which are written in the backward direction.

US Patent No. 5,852,469 relates to encoding and decoding systems for code words with variable lengths and code words with specified lengths. It is provided, for code words with specified lengths, to provide synchronous positions in the data stream whose distance is equal to the length of the

code words of specified lengths. The code words are then entered into the data stream such that they all start at a synchronous position. For code words of variable lengths, a data stream with a start and an end, however without synchronous positions, is provided in order to enter code words of variable lengths in the forward direction, starting from the start of the data stream up to a certain position behind the center of the data stream. Starting from the end of the data stream up to the predetermined position in the center, code words of variable lengths are then entered in the opposite direction of writing.

Summary of the Invention

It is the object of the present invention to render code words of variable lengths more error-robust.

~~This object is achieved by an apparatus for producing a data stream in accordance with claim 1, by an apparatus for reading a data stream in accordance with claim 12, by a method for producing a data stream in accordance with claim 18 and a method for reading a data stream in accordance with claim 19.~~

In accordance with a first aspect of the present invention, this object is achieved by an apparatus for producing a data stream, which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths which are divided up into a plurality of sets of code words, the apparatus comprising: a first device for writing at least a part of each code word of a first set of code words into the data stream in a first direction of writing, starting at a first raster point of a segment, respectively; a second device for writing at least a part of a code word of a second set of code words into the data stream in a second direction of

writing, which is opposite to the first direction of writing, starting from a second raster point, respectively, the code words of the second set being assigned to segments in accordance with a predetermined assignment rule, such that each code word of the second set is assigned to a different segment, wherein, in case that a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment, in accordance with a predetermined rule, by the first device or the second device, after the second device for writing has processed all remaining segments with the other code words of the second set.

In accordance with a second aspect of the present invention, this object is achieved by an apparatus for reading a data stream which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, wherein the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set being assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined rule, the apparatus comprising the following: a first apparatus for reading in a first direction of reading which corresponds to the first direction of writing; a second device for reading in a second direction of reading which is opposite to the first direction of reading; and a control device for supplying the code words of the first set to the first reading device, each code word of the first set starting at the first raster point of a segment, and for supplying the code words of the second

set to the second reading device, wherein one jumps to the second raster point of a segment in accordance with the predetermined assignment rule, and wherein, after all segments have been searched for code words of the second set and at least one code word of the second set is not present or not complete, one jumps at least to one further segment in accordance with the predetermined rule in order to obtain the at least one code word of the second set completely or a part of the at least one code word.

In accordance with a third aspect of the present invention, this object is achieved by a method for producing a data stream, which comprises a multitude of raster points (41 – 47) as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths, which are divided up into a plurality of sets of code words, the method comprising the following steps: writing at least a part of each code word of a first set of code words into the data stream in a first direction of writing, starting from a first raster point of a segment, respectively; writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing which is opposite to the first direction of writing, starting from a second raster point of a segment, respectively, the code words of the second set being assigned to segments in accordance with the predetermined assignment rule, such that each code word of the second set is assigned to a different segment, wherein, in case a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment in the first or second direction of writing, in accordance with a predetermined regulation, after all remaining segments have been processed with the other code words of the second set.

In accordance with a fourth aspect of the present invention, this object is achieved by a method for reading a data stream which comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, in which method the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set is assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined regulation, the method comprising the following steps: reading the code words of the first set, starting from a first raster point of a segment, in a first direction of reading which corresponds to the first direction of writing; reading the code words of the second set, starting from a second raster point of a segment, in a second direction of reading which is opposite to the first direction of reading wherein it is jumped, for reading the code words of the second set, to the second raster point of a segment in accordance with the predetermined assignment rule, wherein, after all segments have been searched for code words of the second set or at least a code word of the second set is not present or not completely present, one jumps to at least one further segment in accordance with the predetermined rule so as to obtain the at least one code word of the second set completely or a part of the at least one code word.

The present invention is based on the realization that the robustness of a data stream toward transmission errors and, in particular, toward sequence errors with code words of variable lengths can be decisively increased when the data stream is not written only in one direction of writing but is written, additionally, in the other direction of

writing. In the most general case, a data stream will always have a start and an end. In the prior art, in the simplest case, the data stream was written onto, starting from the starting point, until it was completed. Thereby it was possible that a transmission error in the first code word could result in that the entire data stream could no longer be decoded correctly, even if all other code words were transmitted correctly. In accordance with the invention, such a data stream may be written such that the first half of the data stream is written starting from the start of the data stream, whereas the second half of the data stream is written starting from the end of the data stream. Even from this simple example, it can be seen that a transmission error in the first half of the data stream no longer has the effect that code words of the second data stream can also no longer be decoded correctly due to sequence errors. This is the case because the decoder knows that after half of the data stream it must continue reading starting from the end of the data stream, to be precise in the opposite direction of reading. Thus, a certain error robustness is obtained merely due to reversing the direction of writing/the direction of reading with virtually no extra effort.

As has already been mentioned, code words with variable lengths are written into a data stream using raster points such that a decoder can decode with a limited number of sequence errors since, by definition, certain code words start at raster points. For maximum error robustness, it will, in principle, be desirable to have a raster which is as narrow as possible, such that a decoder can find the correct starting points of as many code words as possible. On the other hand, an increase in the number of raster points, i.e. a reduction of the segment length, will result in that fewer and fewer code words which, as is known, have variable lengths, completely fit into the raster, which is why measures are taken for the end sections of the same to be written into other segments in order to be able to be

detected correctly in decoding. This leads to an increasing additional effort with a raising number of raster points and with a reduction in the segment length.

In the prior art, code words were written merely in one single direction of writing, starting from a raster point, as has been explained with reference to Figures 5 and 6. In accordance with the invention, code words are now also written in the opposite direction of writing, starting from raster points, which causes the number of the code words which can be written starting at raster points to double, in the best case, essentially without any additional effort. By writing the data stream by means of a device for writing in a first direction of writing starting from a reference point and by means of a second device for writing in a second direction of writing which is opposite to the first direction of writing, starting from a different reference point, it becomes possible to not only utilize "one side" of a reference point, but both sides of a reference point for error robustness, i.e. for protection against propagation or sequence errors. Depending on the form of implementation, every other code word can be written in the same direction, for example, and every remaining code word can be written in the other direction. On the other hand, the code words of variable lengths can be divided up into different sets of code words, for example in accordance with their priority, such that, for example, all code words of the first set are written in the first direction of writing, starting at raster points, and all code words of the second set can be written in the second direction of writing, starting at raster points.

In addition, remainders of code words may be written in the same direction of writing as the starting sections of the code words or, alternatively, in the opposite direction of writing. It is evident that measures must be taken in order for a decoder, i.e. an apparatus for reading the data stream, to always be fully aware of which direction of

writing has been used in writing. This may either be specifically set or be transmitted as side information to the data stream of code words of variable lengths. The same applies also to the segment lengths, wherein the segment length may either be equal or vary over the entire data stream, wherein the current segment length can of course also be specifically set in a decoder or can be transmitted via side information together with the code words of variable lengths.

Brief Description of the Drawings

Preferred embodiments of the present invention will be explained in detail below with reference to the attached drawings, in which:

Fig. 1 shows an inventive apparatus for writing an error-robust data stream;

Fig. 2 shows an inventive apparatus for reading an error-robust data stream;

Fig. 3 shows a procedural diagram of the inventive method by means of three sets of code words of variable lengths;

Fig. 4 shows a procedural diagram for illustrating the inventive method for reading a data stream which has been produced in accordance with Fig. 3;

Fig. 5 shows a data stream which is produced by a known apparatus and in which the priority code words are exposed to error propagation;

Fig. 6 shows a data stream in which sorting by priority code words and non-priority code words has been carried out.

Detailed Description of preferred Embodiments

Before Fig. 1 will be described in more detail, it should be noted that encoding with code words of variable lengths is also referred to as entropy encoding in the art. One representative example of entropy encoding is the so-called Huffman encoding. In principle, in Huffman encoding, the information symbols to be encoded are statistically examined in order to determine shorter code words for the information symbols occurring more frequently than for information symbols occurring less frequently. In a complete Huffman code, all code words are terminated ends or branches of a code tree. For example, a Huffman decoder serially reads in a data stream with Huffman code words and, put graphically, jumps to a branching of the specified code tree with each bit that it reads in additionally until, after a certain number of jumps, which corresponds to the number of bits of the code word, i.e. to the length of the code word, it arrives at a branch end which does not have any further branching and is therefore a code word. The decoder then knows that a new code word starts with the next bit. This process is repeated as often as required until the data stream has been completely read in. With each time that the Huffman encoder jumps back to the starting point, i.e. to the root of the tree, a code word is present at its point of origin. Since the lengths of the code words are implicitly specified by the code words themselves or by the code tree known in the encoder and in the decoder, it can be seen that an interference in the data stream which leads to a reversal of a bit misleads the decoder in the code tree, so to speak such that it ends up with a different code word, i.e. an incorrect code word, which is very likely to have a different length from the correct code word. In this case, the decoder will, once it has arrived at the incorrect code word, jump back and, due to the bits then following, again move from one branching point to another in the code tree. However, it is not

possible for the decoder to avoid a sequence error, unless it coincidentally ends up on the "correct track".

Therefore, error protection, as is provided by the present invention, must be performed in order to ensure error-robust transmission. The apparatus for producing a data stream of code words of variable lengths in accordance with the present invention may therefore act as a sending or output stage of a Huffman encoder, as it were, whereas the apparatus for reading a data stream of code words of variable lengths may act as a receiving or input stage of a Huffman encoder. It can be seen from this that the present invention is not only applicable to Huffman encoders, but to any code having code words of variable lengths which is susceptible to sequence errors.

Figure 1 shows an apparatus 10 in accordance with the invention for producing an error-robust data stream at an output 12, when code words of variable lengths are input into the apparatus 10 at an input 14. The apparatus includes a first device 16 for writing in a first direction of writing, starting from a first reference point, and a second device 18 for writing in a second direction of writing, starting from a second reference point. Depending on the complexity of the apparatus 10, the code words of variable lengths may both be applied to both devices 16 and 18 for writing, as is illustrated in Figure 1 by a simple branching point 20 and a corresponding combination point 22. The selection as to which code words are written in which direction, and/or as to which sections of code words are written in which direction, would then be made by devices 16 and 18. Instead of the node 20, a demultiplexer may be present alternatively, which supplies certain code words, for example code words of a set of code words, to the first device 16, and supplies certain code words to the second device 18. By analogy therewith, the combination point 22 would then be implemented by a multiplexer multiplexing the error-robust data stream 12. Other

devices, which would be controlled correspondingly, for supplying the two devices 16 and 18 with the code words of variable lengths are apparent for those skilled in the art in view of the present description.

An apparatus 30 for reading an error-robust data stream, which apparatus is complementary to the apparatus 10 for producing a data stream, shown in Figure 1, is shown in Figure 2. Apparatus 30 includes an input 32, where the error-robust data stream is entered after transmission via a radio link for example, in order to obtain, again, at a starting point 34, the code words of variable lengths which have been fed into the input 14 of the apparatus 10 in Figure 1. Apparatus 30 for reading the data stream includes a first device 36 for reading in the first direction, starting from the first reference point, and a second device 38 for reading the data stream in the second direction, starting from a second reference point.

It is evident that apparatus 30 also contains a branching point 40 and a combination point 42, the feeding-in of the error-robust data stream into the two devices 36 and 38 taking place, for example, based on a specifically set algorithm or based on side information which may also be transmitted, together with the error-robust data stream, from the sender, i.e. the apparatus 10 in Figure 1, to the receiver, i.e. the apparatus 30 in Figure 2.

Fig. 3 illustrates, by means of an example, the inventive method for writing code words of variable lengths. In the example, there are 15 code words of variable lengths 30 which are preferably divided up into a first set having 6 code words 1 to 6, into a second set also having 6 code words 7 to 12 and into a third set having the remaining 3 code words 13 to 15. As is shown in Fig. 3, code words 30 have variable lengths.

In accordance with a preferred embodiment of the present invention, the segment length, i.e. the length of the segment, is longer than the length of the longest code word of the first set. The code words of the first set are arranged at raster points 41 to 46, wherein, for the last segment No. 6, a raster point is indicated by a dotted line, which raster point is not used, however, since the end 47 of the data stream can also be considered as a raster point as it were and since the raster point indicated by a dotted line is thus superfluous. The first segment No. 6 is therefore longer than the other segments, which is completely irrelevant for the present invention, however. Generally speaking, the segments may have any lengths, which change within the data stream, it being understood that the current length of a segment must be known to the decoder so that the inventive advantages can be utilized.

Firstly, the code words of the first set are written into the data stream in a step a), which results in a fragmentary data stream indicated by 31, in which the code words of the first set are written into a respective segment from left to right, as is indicated by arrows 48 which are to symbolize the direction of writing in the entire Fig. 3. Since the segment length is selected to be longer than the longest length of a code word of the first set, only one single attempt is needed for step a). In case the segments are shorter, more attempts may be required accordingly.

Now the code words of the second set are written into the data stream 31 in a step b). In order to achieve high error robustness, the code words of the second set are not written from left to right like the code words of the first set, but are written from right to left, starting from the second raster point, respectively, e.g. the raster point 42 for the first segment, as is indicated by the respective arrow of writing direction. The writing of the code words

of the second set takes place in accordance with a predetermined assignment rule which says, in the example selected, that the first code word of the second set is to be written in the same segment as the first code word of the first set, however always on the condition that there is still room in this segment. The data stream 32 resulting from the first attempt shows that in the first segment there was only so much room for writing the starting section of code word No. 7.

In contrast to the prior art, where the second part of code word No. 7 would have been written into the second segment, the second half of code word No. 7, i.e. 7 b), is stored for writing it into the data stream in a second attempt in accordance with a predetermined regulation, i.e. in accordance with an regulation which must also be known to the decoder. Fig. 3 clearly shows that in the second segment, there was still enough room between code word Nos. 2 and 8 for the final section of code word No. 7 to be entered. In case there had not been enough room, the third section of the code word would have been entered into segment No. 3. Thus, in Fig. 3, the predetermined regulation for entering code word No. 7 into the data stream consists in proceeding by one segment in each case. Of course, one may also proceed by two segments or by three or more, such that, as a consequence, the second segment 7 b) could then be written, instead of the second segment, into the third, into the fifth in the next attempt, etc. The order of segments which is used to accommodate the second part of section 7 somewhere is arbitrary. However, it must be transparent to the decoder so that the re-sorted data stream can be re-read.

The code words of the third set 13 to 15 are now to be entered into the resulting data stream 33, which is also still fragmentary. By analogy with step b), this is done preferably by the same assignment rule such that the first code word of the third set is assigned to the first

segment, that the second code word of the third set is assigned to the second segment, that the third code word of the third set is assigned to the third segment, etc. This assignment rule is entirely arbitrary for the third set and may also be different from the assignment rule for the second set, with each code word of a set being assigned to a different segment in accordance with the invention. Similarly, the direction of writing can also be selected arbitrarily for each set. Preferably, an alternating writing direction order is used. Alternatively, however, it is also possible to write two adjacent sets using the same direction of writing. In principle, the writing direction may also altered within a set.

The first attempt in step c) was successful only in that the first section of code word No. 15 was entered, resulting in a fragmentary data stream 34. Code words 13, 14 and the second section of code word 15, i.e. 15 b) are stored for being accommodated in the second, third, fourth, fifth and sixth attempts, wherein the second section 15b could be accommodated in the fourth segment in the second attempt (data stream 35), wherein nothing could be accommodated in the third attempt, wherein the starting section of code word 14 could be accommodated in the fourth attempt (data stream 36), wherein the final section of code word 14, i.e. 14b could be accommodated in the fifth attempt (data stream 37) and wherein, finally, the first code word of the third set could be entered in the sixth segment in the sixth and final attempt, which results in the error-robust data stream 38 for the example illustrated here. The method described using Fig. 3 ensures that the length of the error-robust data stream exactly corresponds to the sum of the lengths of the code words of variable lengths, which is self-evident for the purposes of entropy encoding for data reduction. However, the present invention is not limited to the error-robust data stream having the minimal length, since error robustness is not affected by any filler bits that may be present.

When looking at the robust data stream shown in Fig. 3, it can be seen that the start of code word No. 8, i.e. raster point 43, is entirely independent of the end of code word No. 7. Moreover, the start of code word No. 9, i.e. raster point 44, is entirely independent of the end of code word No. 8. Additionally, it should be noted that due to the opposite writing order, a data error in code word No. 1 in the first segment, for example, which leads to the fact that the incorrect code word is one bit shorter than the correct code word No. 1 due to the data error, does not lead to a destruction of the starting section of code word No. 7a, since the latter was written from right to left instead of from left to right. In case it had been written from left to right, a decoder would take the remaining bit from the initially correct code word No. 1 as the starting bit of code word No. 7, which would result in a sequence error from 1 to 7. However, this sequence error would not propagate to 8, since code word No. 8, again, is entirely independent of code word No. 7, since the writing order was chosen to be from right to left. In case the writing order of code word No. 8 is equal to the writing order of the code words of the first set, the error would not propagate from 7 to 8 either, since code word No. 8 would be written adjacent to code word No. 2 before the second part 7b due to the assignment rule and is, therefore, not influenced by an incorrect section 7b.

By means of an appropriate example, Fig. 4 shows the operation of the apparatus for reading the error-robust data stream 38. Initially, the code words of the first set are extracted from the error-robust data stream in step a). For this purpose, the inventive apparatus, which may be coupled to a Huffman decoder, reads the code word of the first set starting from the first raster point 41, reads code word No. 2 of the first set starting from the second raster point 42, etc., until all code words 1 to 6 of the first set have been read in. It is self-evident that the

apparatus for reading the data stream selects the same direction as has been used by the apparatus for producing.

Subsequently, the code words of the second set are extracted from the remaining data stream 50 in step b). Here, the decoder jumps to the second raster point 42 of the first segment and obtains the starting section of code word 7 of the second set (the first segment is now empty), whereupon it does not read in the second section 7b, but 7a is first stored in order to then read in the second code word of the second set starting from the second raster point of the second segment, etc. The result is a residual data stream 51 in which the first segment has been completely emptied. Since the decoder does not now read the code word 7 continuously, but always reads segment by segment on the basis of the assignment rule used for the apparatus for producing the data stream, the error robustness which has already been described and which strongly reduces propagation of sequence errors is ensured.

In a second attempt for extracting the code words of the second set, the second part of code word 7b is now read in the second segment in accordance with the existing writing direction, whereupon only code words of the third set remain in the resulting data stream 52, and the second segment is empty. These are extracted in step c), wherein the starting section of code word 15 has been initially determined in a first attempt, which is not stored however, since code word 15 has not been found complete in the third segment. The third segment is now empty. In a second attempt, code word 15 can be found complete. However, the search for code word 14 in segment 3 and for code word 15 in segment 14 remained without success, which can be seen by the data stream 54. Nevertheless, in the fourth attempt, the search for code word 14 in the fifth segment lead to a positive result. However, code word 14 was not complete, which is why the starting section 14a was stored in order to examine the remaining data stream 55 in a fifth attempt

and to fully read in, in a final sixth attempt, data stream 56, which now only consists of the sixth segment and of code word 13.

Even though in the previous example merely a division of code words into a starting section and a final section was illustrated by way of example, any type of division is possible in principle. Error-robust decoding will be ensured as long as the decoder observes the assignment of code words of the second set or of the third set and of further sets to different segments, respectively. Moreover, it is obvious that the sorting of the final sections of code words into the data stream is arbitrary as long as the decoder or the read-in circuit upstream of the decoder knows exactly which predetermined regulation has been carried out in the encoder.

In order to once again underline the advantages and/or the operation of the present invention, reference is made to the error-robust data stream No. 38 of Figure 3. When looking at the first segment between the raster points 41 and 42, it can be seen that code word No. 1 is written from left to right, starting from the first raster point 41, as is clearly indicated by the arrow drawn underneath. The first part of code word No. 7, i.e. 7a, however, is written from right to left, starting from the second raster point 42. If both code words No. 1 and No. 7 or 7a were written into the data stream only from left to right, the start of code word 7 or the starting point of the starting section 7a of code word 7 would depend on the end of code word 1. Therefore, a transmission error in code word 1 would almost inevitably also lead to a sequence error in code word 7. However, if code word 7 is written in the opposite direction of writing, starting from the second raster point 42, in accordance with the invention, the starting point of code word 7 or of starting section 7a of code word 7 no longer depends on code word 1 but is determined by the raster or raster point 42. A decoder will always know this

starting point, which is why an error in code word 1 will not lead to an error in code word 7. It can be seen from the error-robust data stream 38 of Figure 3 that the first section 7a and the second section 7b of code word No. 7 are both written in the same direction of writing. However, this is not compulsory. Of course, the second section 7b of code word 7 may also be written from left to right and would then start at the end of the second code word No. 2.

If the raster points are chosen such that the segment lengths are longer than the longest length of a code word of the first set, no segment will be filled in completely by the code word of the first set, as can be seen, for example, from the data stream 31 of Figure 3. In this case, the number of code words which can be written starting at raster points is actually doubled without there being any need of providing one single additional raster point.

Claims

1. Apparatus ~~(10)~~ for producing a data stream ~~(38)~~, which comprises a multitude of raster points ~~two~~ as reference points ~~(41 - 47)~~, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths which are divided up into a plurality of sets of code words, the apparatus comprising:

a first device ~~(16)~~ for writing at least a part of ~~a~~ each code word of a first set of code words into the data stream in a first direction of writing, starting ~~from~~ at a first ~~reference~~ raster point of a segment, respectively;

a second device ~~(18)~~ for writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing, which is opposite to the first direction of writing, starting from ~~the other reference~~ a second raster point, respectively, the code words of the second set being assigned to segments in accordance with a predetermined assignment rule, such that each code word of the second set is assigned to a different segment,

wherein, in case that a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment, in accordance with a predetermined rule, by the first device or the second device, after the second device for writing has processed all remaining segments with the other code words of the second set.

~~2. Apparatus as claimed in claim 1, wherein the two reference points of the data stream are the start (41) and the end (47) of the data stream, respectively.~~

~~3.~~2. Apparatus as claimed in claim 1, wherein the first writing device ~~(16)~~ is arranged so as to write a starting section of a code word, and wherein the second writing device ~~(18)~~ is arranged so as to write at least a part of the remainder of the same code word.

~~4. Apparatus as claimed in claim 1, wherein the data stream comprises a multitude of raster points (41 - 46) as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, the first writing device (16) being arranged so as to write a first code word which starts at a first raster point of a segment, and the second writing device (18) being arranged so as to write a second code word which starts at the second reference point of the segment.~~

~~5.~~3. Apparatus as claimed in claim 1, wherein the data stream comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, the first writing device ~~(16)~~ being arranged so as to write a starting section of a first code word at a first raster point of a first segment and to write a starting section of a second code word at a first raster point of a following segment, and the second writing device ~~(18)~~ being arranged so as to write at least a part of the remainder of the first code word starting from the second ~~reference~~ raster point of the second segment and to write the remainder of the second code word starting from the second ~~reference~~ raster point of a further segment, respectively.

~~6. Apparatus as claimed in any of the preceding claims, wherein the code words are divided up into a plurality of sets of code words, the first device (16) for writing being arranged so as to write each code word of the first set into the data stream, starting from a first reference point of a segment, and the second writing device (18) being arranged so as to write each code word of the second set into the data stream, starting from a second reference point of a respective segment.~~

~~7.~~4. Apparatus as claimed in claim ~~6~~ 1, wherein the second writing device ~~(18)~~ is arranged so as to write starting from the second ~~reference~~ raster point of the segment into which the first writing device ~~(16)~~ has written, wherein, if the respective code word of the second set is longer than a vacant space in the segment, the part of the code word of the second set which fits into the vacant space is written into the segment, and the remainder is initially stored.

~~8.~~5. Apparatus as claimed in claim ~~6 or 7~~ 1, wherein the second writing device ~~(18)~~ is arranged so as to become active only once all code words of the first set have been written into the data stream.

~~9.~~6. Apparatus as claimed in claim ~~8~~ 4, wherein the second writing device ~~(18)~~ is arranged so as to write at least a part of the remainder of the code word of the second set ~~to the end of a code word of the second set as a reference point~~ into the data stream, starting from the end of a different code word of the second set.

~~10. Apparatus as claimed in any of claims 6 to 9, wherein the code words of the second set are assigned to segments in accordance with a predetermined assignment rule, such that each code word of the second set is~~

~~assigned to a different segment, and wherein the second writing device (18) is arranged so as to write, in the event that a code word of the second set no longer fits into the assigned segment, the remainder into a non-fully occupied other segment, after it has processed all remaining segments with the other code words of the second set.~~

~~11.~~7. Apparatus as claimed in ~~any of claims 4 to 10~~ claim 1, wherein the code words are divided up into at least three sets, the first writing device ~~(16)~~ being arranged so as to write the code words of the first set starting from first raster points of segments, the second writing device ~~(18)~~ being arranged so as to write the code words of the second set starting from the other raster points of the segments, the first or second writing device ~~(16, 18)~~ further being arranged so as to write the third set starting from ends of the code words of the first and the second set, respectively.

8. Apparatus as claimed in claim 7, wherein the first or the second writing device is further arranged so as to write the third set starting from ends of the code words of the first and second set, respectively, in accordance with a predetermined assignment rule, such that each code word of the third set is assigned to a different segment.

~~12.~~9. Apparatus ~~(30)~~ for reading a data stream ~~(32)~~ which comprises ~~two~~ a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, wherein the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data

stream in accordance with a predetermined assignment rule, such that each code word of a set being assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined rule ~~starting from which at least a part of a code word is written in a first or second writing direction~~, the apparatus comprising the following:

a first apparatus ~~(36)~~ for reading~~, starting from the first reference point,~~ in a first direction of reading which corresponds to the first direction of writing;

~~and~~ a second device ~~(38)~~ for reading~~, starting from the second reference point,~~ in a second direction of reading which is opposite to the first direction of reading; and

a control device

for supplying the code words of the first set to the first reading device, each code word of the first set starting at the first raster point of a segment, and

for supplying the code words of the second set to the second reading device, wherein one jumps to the second raster point of a segment in accordance with the predetermined assignment rule, and

wherein, after all segments have been searched for code words of the second set and at least one code word of the second set is not present or not complete, one jumps at least to one further segment in accordance with the predetermined rule in order to obtain the at least one code word of the second set completely or a part of the at least one code word.

~~13. Apparatus as claimed in claim 12, wherein the data stream comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, wherein the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set is assigned to a different segment, the apparatus further comprising the following:~~

~~a control device (40) for supplying the code words of the first set to the first writing device (36), the code word of the first set starting at a raster point, and for supplying the code words of the second set to the second reading device (38), wherein, in accordance with the predetermined assignment rule, one jumps to corresponding raster points, wherein it is verified, if no code word is found at a reference point, whether code words of the second set are present at corresponding raster points in accordance with the assignment rule and wherein, after all code words of the second set have been read, one jumps to a different raster point in accordance with the predetermined rule, in order to obtain all code words of the second set completely.~~

~~14~~ 10. Apparatus as claimed in claim ~~13~~ 9, wherein, if only one starting section of a code word is read by a writing device in one segment, this starting section is stored.

~~15.~~ 11 Apparatus as claimed in ~~any of the preceding claims~~claim 9, wherein the code words are Huffman code words.

~~16~~12. Apparatus as claimed in ~~any of the preceding claims~~claim 9, wherein the code words represent information symbols and wherein code words of the first set represent more significant information symbols than code words of the second set or of further sets.

~~17~~ 13. Apparatus as claimed in claim ~~16~~ 12, wherein the information symbols are spectral values of an audio signal, and wherein the code words of the first set are spectral values which are significant from a psycho-acoustic point of view and which are to be protected from error propagation due to a transmission error in the data stream.

~~18~~ 14. Method ~~(10)~~ for producing a data stream ~~(38)~~, which comprises a multitude of raster points (41 - 47) as ~~two~~ reference points ~~(41) to (47)~~, the raster points specifying a raster, two adjacent raster points defining a segment, of code words of variable lengths, which are divided up into a plurality of sets of code words, the method comprising the following steps:

writing at least a part of ~~a~~ each code word of a first set of code words into the data stream in a first direction of writing, starting from a first ~~reference~~ raster point of a segment, respectively;

writing at least a part of a code word of a second set of code words into the data stream in a second direction of writing which is opposite to the first direction of writing, starting ~~from the other reference point~~ from a second raster point of a segment, respectively, the code words of the second

set being assigned to segments in accordance with the predetermined assignment rule, such that each code word of the second set is assigned to a different segment, wherein, in case a code word of the second set does not or not completely fit into the assigned segment, at least a part of this code word or at least a part of the remainder of this code word which does not fit into the assigned segment is written into a different, not fully occupied segment in the first or second direction of writing, in accordance with a predetermined regulation, after all remaining segments have been processed with the other code words of the second set.

~~19~~ 15. Method ~~(30)~~ for reading a data stream ~~(32)~~ which comprises ~~two reference points, from which at least a part of a code word is written in a first and a second direction of writing, respectively~~ a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, in which method the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set is assigned to a different segment, wherein a code word of the second set may be divided up over more than one segment in accordance with a predetermined regulation, the method comprising the following steps:

reading the code words of the first set, starting from ~~the~~ a first ~~reference~~ raster point of a segment, in a first direction of reading which corresponds to the first direction of writing; ~~and~~

reading the code words of the second set, starting from ~~the~~ a second raster ~~reference~~ point of a segment, in a second direction of reading which is opposite to the first direction of reading wherein it is jumped, for reading the code words of the second set, to the second raster point of a segment in accordance with the predetermined assignment rule, wherein, after all segments have been searched for code words of the second set or at least a code word of the second set is not present or not completely present, one jumps to at least one further segment in accordance with the predetermined rule so as to obtain the at least one code word of the second set completely or a part of the at least one code word.

Apparatus and Method for Producing a Data Stream and Apparatus and Method for Reading a Data Stream

Abstract

An entropy encoder includes an apparatus ~~(10)~~ for producing a data stream which comprises two reference points, of code words of variable lengths, the apparatus comprising a first device ~~(16)~~ for writing at least a part of a code word into the data stream in a first direction of writing, starting from a first reference point, and a second device ~~(18)~~ for writing at least a part of a code word into the data stream in a second direction of writing, which is opposite to the first direction of writing, starting from the other reference point. In particular, when a raster having a plurality of segments is used to write the code words of variable lengths into the data stream, the number of the code words which can be written starting at raster points is doubled, in the best case, such that the data stream of code words of variable lengths is robust toward a propagation of sequence errors.

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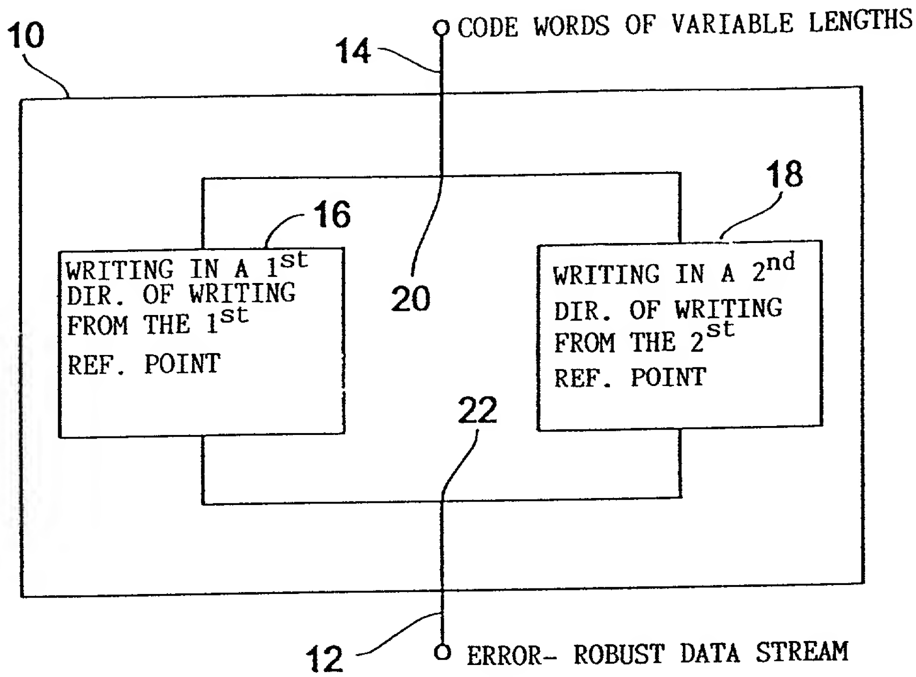


Fig. 1

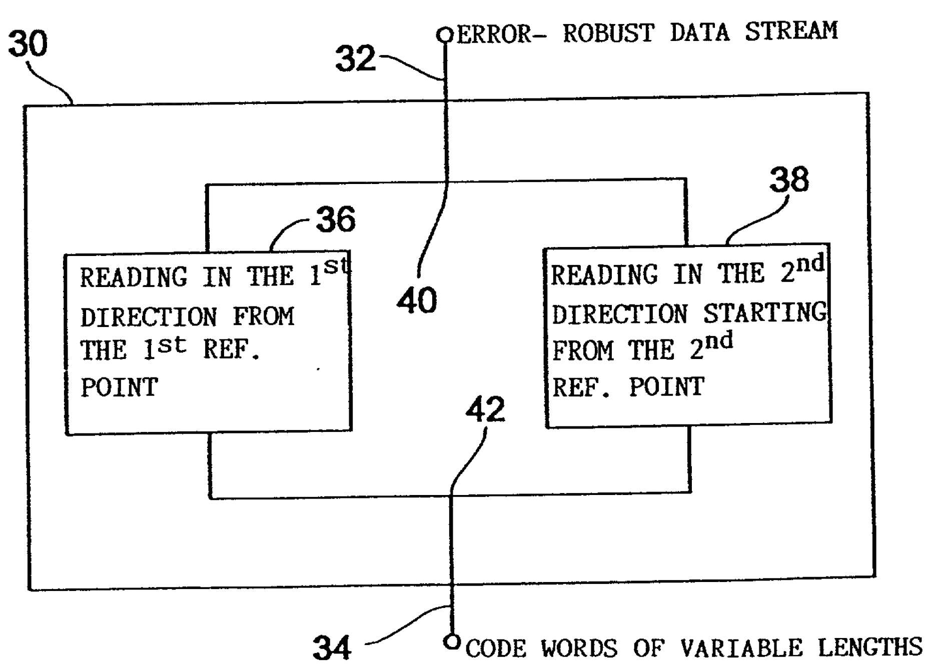


Fig. 2

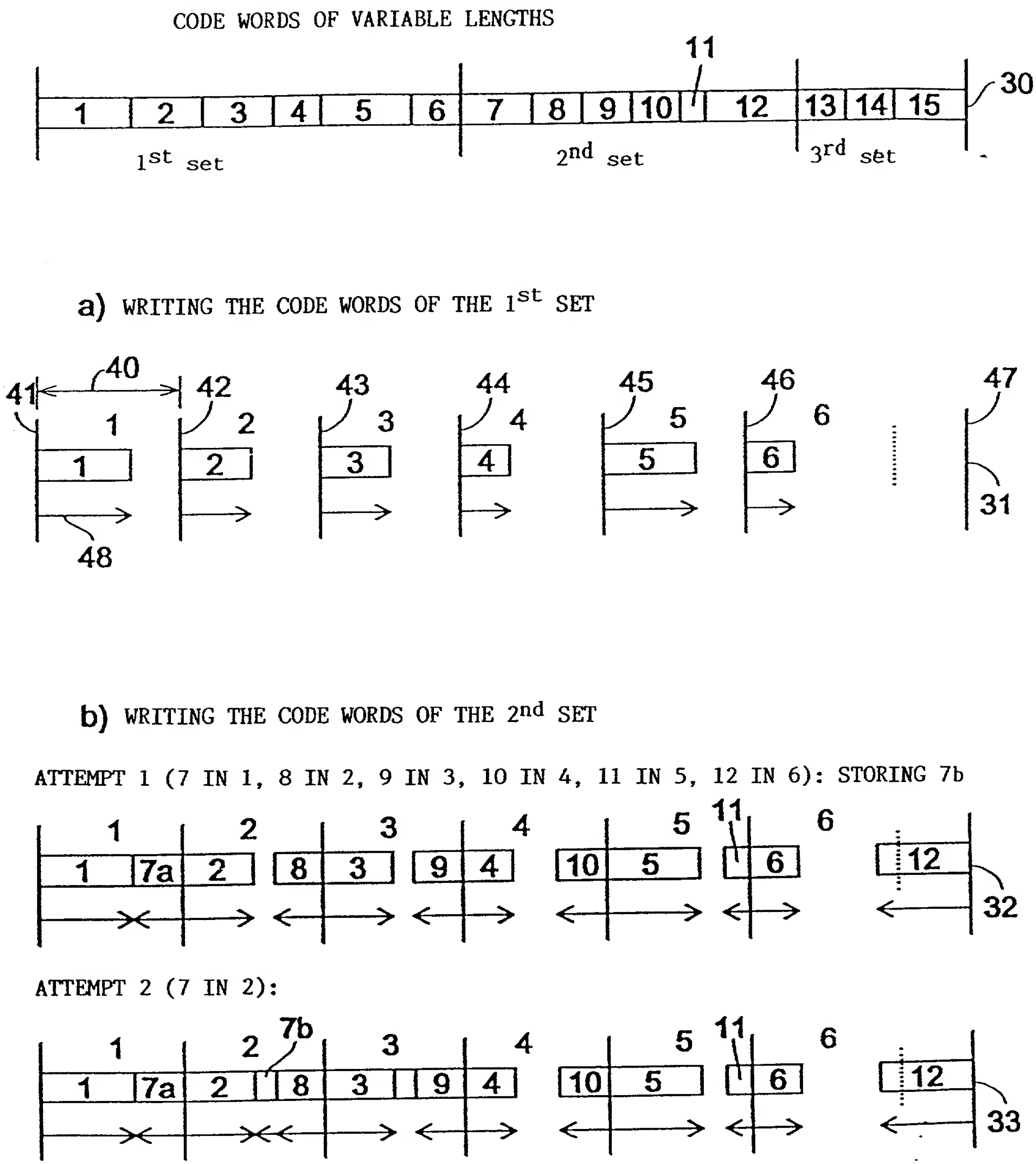
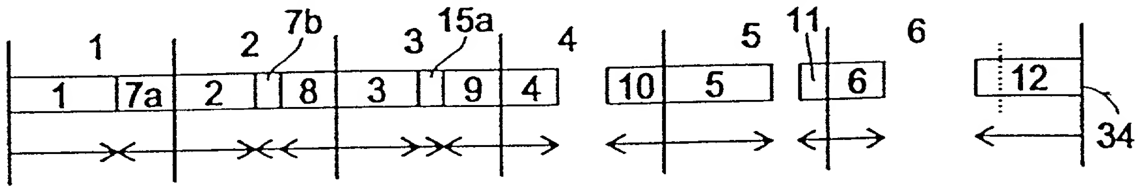

CODE WORDS OF VARIABLE LENGTHS
1st set
2nd set
3rd set
a) WRITING THE CODE WORDS OF THE 1st SET
b) WRITING THE CODE WORDS OF THE 2nd SET
ATTEMPT 1 (7 IN 1, 8 IN 2, 9 IN 3, 10 IN 4, 11 IN 5, 12 IN 6): STORING 7b
ATTEMPT 2 (7 IN 2):

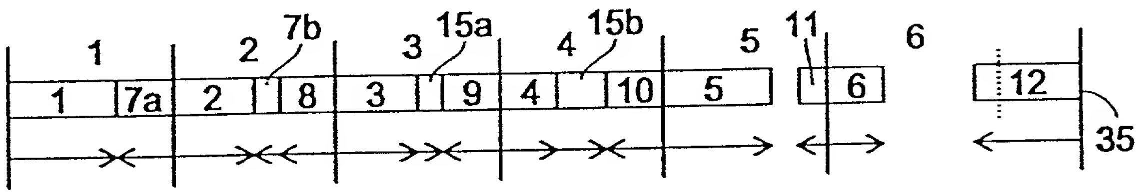
Fig. 3

c) WRITING THE CODE WORDS OF THE 3rd SET

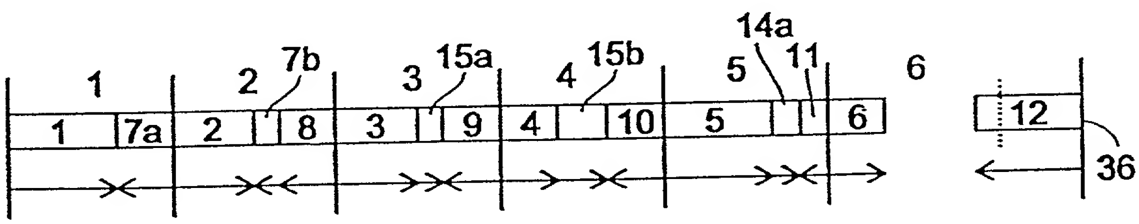
ATTEMPT 1 (13 IN 1, 14 IN 2, 15 IN 3): STORING 13, 14, 15b



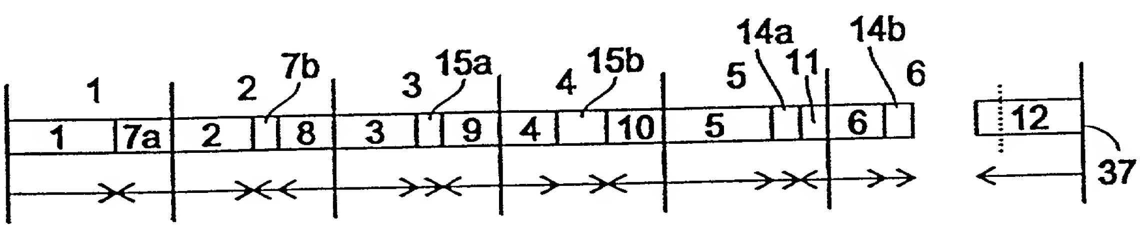
ATTEMPT 2 (13 IN 2, 14 IN 3, 15 IN 4): STORING 13, 14



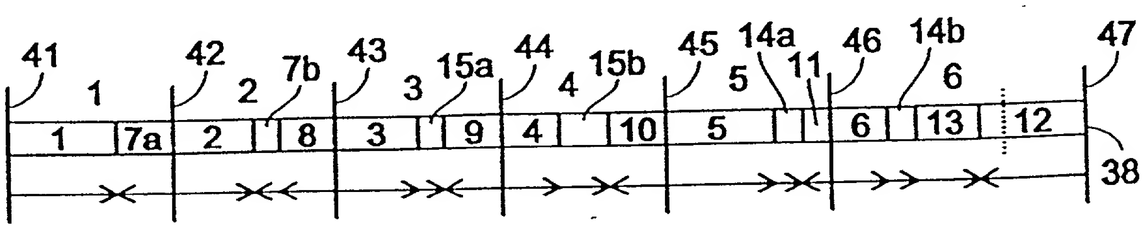
ATTEMPT 3 (13 IN 3, 14 IN 4): STORING 13, 14
ATTEMPT 4 (13 IN 4, 14 IN 5): STORING 13, 14b



ATTEMPT 5 (13 IN 5, 14 IN 6): STORING 13



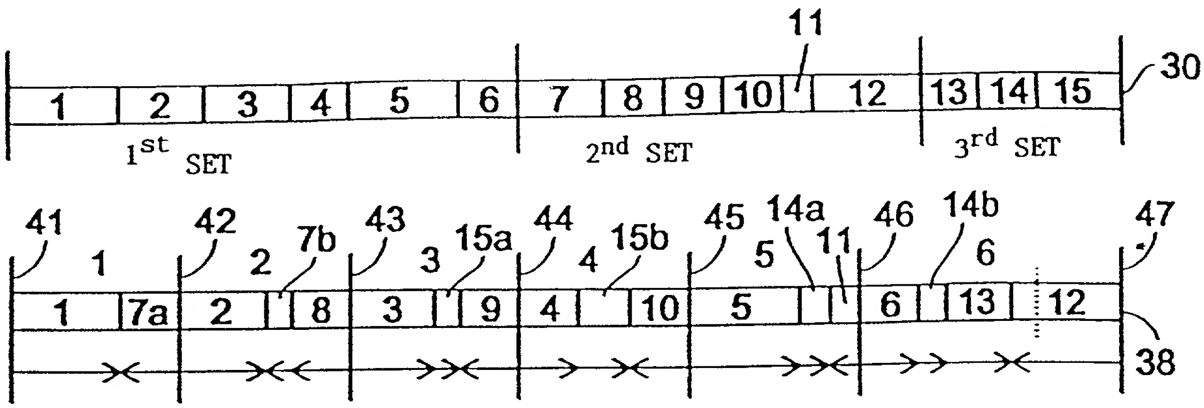
ATTEMPT 6 (13 IN 6)



ERROR- ROBUST DATA STREAM

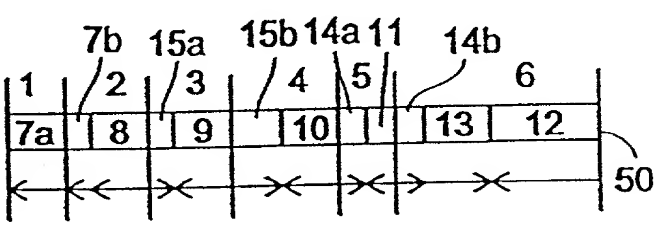
Fig. 3

CODE WORDS OF VARIABLE LENGTHS



ERROR- ROBUST DATA STREAM (FIG. 3)

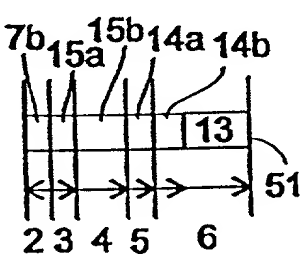
a) EXTRACTING THE CODE WORDS OF THE 1st SET



b) EXTRACTING THE CODE WORDS OF THE 2nd SET

ATTEMPT 1 (SEARCHING 7 IN 1, 8 IN 2, 9 IN 3, 10 IN 4, 11 IN 5, 12 IN 6)

STORING 7a



ATTEMPT 2 (SEARCHING 7 IN 2)

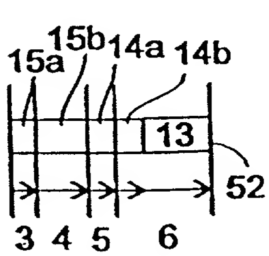


Fig. 4

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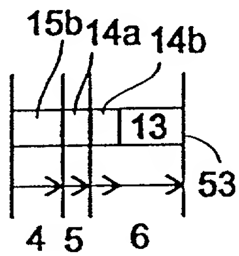
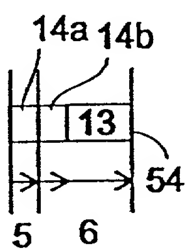
c) EXTRACTING THE CODE WORDS OF THE 3rd SET

ATTEMPT 1 (SEARCHING 13 IN 1, 14 IN 2, 15 IN 3)

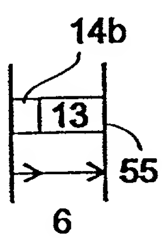


STORING 15a

ATTEMPT 2 (SEARCHING 13 IN 2, 14 IN 3, 15 IN 4)

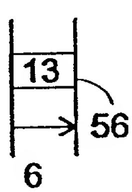


ATTEMPT 3 (SEARCHING 13 IN 3, 14 IN 4)
ATTEMPT 4 (SEARCHING 13 IN 4, 14 IN 5)



STORING 14a

ATTEMPT 5 (SEARCHING 13 IN 5, 14 IN 6)



ATTEMPT 6 (SEARCHING 13 IN 6)

Fig. 4

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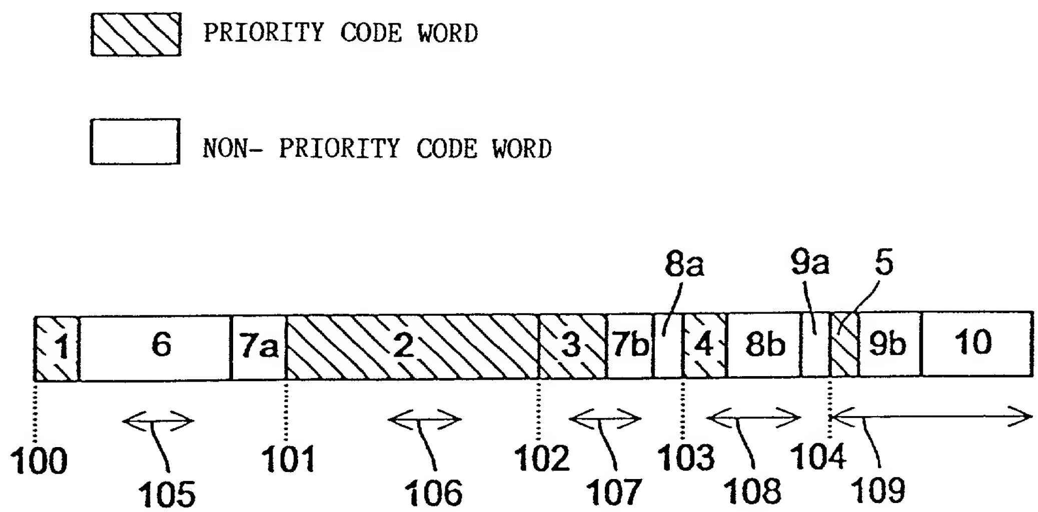

Fig. 5 (PRIOR ART)

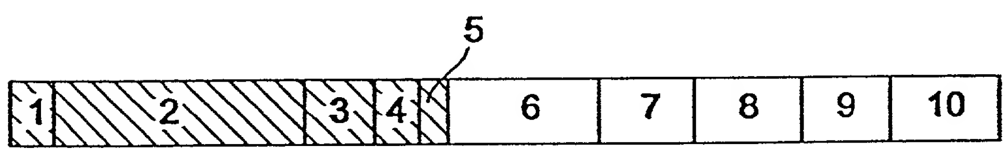

Fig. 6 (PRIOR ART)

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JC09 Rec'd PCT/PTO 16 AUG 2001

National Phase of PCT/EP00/00314 in U.S.A.
Title: Apparatus and Method for Producing a Data stream and Apparatus and Method for Reading a Data stream
Applicant: SPERSCHNEIDER; DIETZ; HOMM; BÖHM

Translation of PCT Application PCT/EP00/00314
as originally filed

6/PRTS

09/913708

JC03 Rec'd PCT/PTO 16 AUG 2001

Apparatus and Method for Producing a Data stream and Apparatus and Method for Reading a Data stream

Description

The present invention relates to encoding with code words of variable lengths and, in particular, to producing and reading data streams with code words of variable lengths, which are robust with regard to errors in transmission.

Modern audio encoding or decoding methods which work by the MPEG layer 3 standard, for example, are capable of compressing the data rate of audio signals, e.g. by a factor 12, without noticeably degrading the quality thereof. In order to achieve such a high data rate reduction, an audio signal is sampled, whereby a sequence of discrete-time samples is obtained. As is known in the art, the sequence of discrete-time samples is windowed in order to obtain windowed blocks of time samples. A block of time-windowed samples is then transformed to the frequency range by means of a filter bank, a modified discrete cosine transform (MDCT) or other suitable device, in order to obtain spectral values which, as a whole, represent the audio signal, i.e. the time section determined by the block of discrete-time samples, in the frequency range. Usually, time blocks which overlap at 50% are produced and transformed to the frequency range by means of a MDCT whereby, due to the specific properties of the MDCT, 1024 discrete-time samples, for example, always lead to 1024 spectral values.

It is known that the receptivity of the human ear depends on the momentary spectrum of the audio signal itself. This dependency is covered in the so-called psycho-acoustic model by means of which it has been possible for quite some time to calculate masking thresholds depending on the momentary spectrum. Masking means that a specific tone or a

spectral component is hidden in case an adjacent spectral range, for example, has relatively high energy. This fact of masking is utilized in order to quantize as closely as possible the spectral values present after the transformation. The aim is therefore to avoid audible interferences in the re-decoded audio signal on the one hand and to use as few bits as possible on the other hand in order to encode or, in this case, to quantize the audio signal. The interferences introduced by quantization, i.e. quantization noise, are intended to be below the masking threshold and, therefore, to be inaudible. In accordance with known methods, a classification of the spectral values in so-called scale factor bands is carried out, which should correspond to the critical bands, i.e. frequency groups, of the human ear. Spectral values in a scale factor group are multiplied by a scale factor in order to carry out overall scaling of spectral values of a scale factor band. The scale factor bands scaled by the scale factor are then quantized, whereupon quantized spectral values are produced. It is understood that grouping in scale factor bands is not critical. However, it is used in the MPEG layer 3 standards or in the MPEG 2 AAC standard (AAC = advanced audio coding).

A very essential aspect of data reduction lies in entropy encoding of the quantized spectral values, which follows quantizing. Huffman encoding is usually used for entropy encoding. A Huffman coding is understood to mean a coding with a variable length, i.e. the length of the code word for a value to be encoded is dependent on the probability of occurrence thereof. Logically, the most probable character is assigned the shortest code, i.e. the shortest code word, so that very good redundancy reduction can be achieved by means of Huffman encoding. An example for a generally-known coding with a general length is the Morse code.

In the field of audio encoding, Huffman codes are used for encoding the quantized spectral values. A modern audio encoder, which works, for example, in accordance with the MPEG 2 AAC standard, uses different Huffman code tables for encoding the quantized spectral values, which Huffman code tables are assigned to the spectrum by certain criteria on a section-by-section basis. In this process, 2 or 4 spectral values are always encoded together in one code word.

One difference between the method in accordance with MPEG 2 AAC and the method in accordance with MPEG layer 3 is that different scale factor bands, i.e. different spectral values, are grouped into any number of spectral sections. With AAC, one spectral section includes at least four spectral values, but preferably more than four spectral values. The entire frequency range of the spectral values is therefore divided up into adjacent sections, with one section representing one frequency band such that all sections together cover the entire frequency range, which is superimposed by the spectral values after the transformation thereof.

As in the MPEG layer 3 method, one section is assigned to a so-called "Huffman table" from a plurality of such tables in order to achieve a maximum redundancy reduction. In the bit stream of the AAC method, which usually comprises 1024 spectral values, are now the Huffman code words for the spectral values in an ascending order of frequencies. The information on the table used in each frequency section is transferred in the side information. This situation is shown in Fig. 6.

Fig. 6 shows the exemplary case where the bit stream includes 10 Huffman code words. In case one code word is always formed from one spectral value, 10 spectral values may be encoded here. However, usually 2 or 4 spectral values are always jointly encoded by one code word, which

is why Fig. 6 shows a part of the encoded bit stream which includes 20 or 40 spectral values. In the case where each Huffman code word includes 2 spectral values, the code word designated by No. 1 represents the first two spectral values, with the length of code word No. 1 being relatively short, which means that the values of the first two spectral values, i.e. of the two smallest frequency coefficients, occur relatively frequently. The code word bearing the No. 2, however, has a relatively long length, which means that the amounts of the 3^{rd} and 4^{th} spectral coefficients in the encoded audio signal are relatively rare, which is why they are encoded with a relatively large amount of bits. Further, it is apparent from Fig. 6 that the code words with the numbers 3, 4 and 5, which represent the spectral coefficients 5 and 6 or 7 and 8 or 9 and 10, also occur relatively frequently, since the length of the individual code words is relatively small. The same applies to the code words bearing the numbers 6 to 10.

As has already been mentioned, it is clearly apparent from Fig. 6 that the Huffman code words for the encoded spectral values are arranged in the bit stream in a linearly ascending manner with regard to the frequency in case a bit stream which is produced by a known encoding apparatus is considered.

One major drawback with regard to Huffman codes, in the case of faulty channels, is error propagation. It may be assumed, for example, that code word No. 2 in Fig. 6 is interfered with. There is a certain, not low, probability that the length of this wrong code word No. 2 is also modified. It therefore is different from the correct length. In case, in the example of Fig. 6, code word No. 2 has been modified in its length due to an interference, it is no longer possible for an encoder to determine the starts of the code words 3 to 10, i.e. of almost the entire audio signal represented. This means that all other code words following the code word which has been interfered

with can no longer be correctly encoded, since it is not known where these code words start, and since an incorrect starting point was selected due to the error.

As a solution to the problem of error propagation, European Patent No. 0 612 156 proposes that a part of the code words of variable lengths be arranged in a raster and that the remaining code words be distributed in the remaining gaps, so that the start of a code word which is arranged at a raster point can be more easily found without full decoding or in the case of an incorrect transmission.

It is true that the known method provides some remedy for error propagation by means of rearranging the code words. For some code words, a fixed location in the bit stream is agreed upon, whereas the remaining gaps are available for the remaining code words. This does not cost any additional bits, but prevents, in the case of an error, error propagation among the rearranged code words.

German Patent Application 19 747 119.6-31, which was published after the filing date of the present application, proposes that not just any code words be located at raster points, but that code words which are significant from a psycho-acoustic point of view, i.e. code words for spectral values which make a significant contribution to the audio signal, be located at raster points. A data stream with code words of variable lengths, such as is produced by such an encoder, is shown in Fig. 5. As in Fig. 6, the data stream also includes 10 code words, with the priority code words being shaded. The first priority code word is located such as to start at a first rater point 100, the second priority code word is located such as to start at a second raster point 101, the third priority code word is located such as to start at a third raster point 102, the fourth priority code word is located such as to start at a fourth raster point 103 and the fifth priority code word is located such as to start at a fifth raster point 104. A

first segment 105 is defined by the raster points 100 and 101. Similarly, a second 106, a third 107, a fourth 108 and a final segment 109 are defined. It is shown in Fig. 5 that the first two segments 105 and 106 have a different length from the two segments 107 and 108 and yet a different length from the final segment 109. Non-priority code words 6, 7, 8, 9 and 10 are then entered in the data stream following the priority code words such that the latter is filled up, so to speak. As is shown in Fig. 5, in the post-published method, the non-priority code words are consecutively inserted in the raster after the priority code words have been written. Specifically, the non-priority code word No. 6 is entered following the non-priority code word 1. The space still remaining in the segment 105 is filled up with the following non-priority code word 7, with the remainder of the non-priority code word 7, i.e. 7b, being written in the next free space, i.e. in the segment 107, directly following the priority code word 3. The same procedure is followed for the non-priority code words 8 to 10.

The advantage of the post-published method illustrated in Fig. 5 is that the priority code words 1 to 5 are protected against error propagation, since their starting points coincide with raster points and are therefore known.

In case, for example, the priority code word 2 has been damaged in transmission, it is very likely in the prior art shown in Fig. 6 that a decoder will not be able to decode any of the remaining code words 3 to 10 correctly. In the method shown in Fig. 5, however, the next code word, i.e. priority code word 3, starts at the raster point 102 such that the decoder will, at any rate, find the correct start of code word 3. Therefore, in the method shown in Fig. 5, no sequence error whatsoever will occur, and only priority code word No. 2 will be damaged. Consequently, this method provides effective protection for priority code words which are located at raster points.

However, there is no effective protection for non-priority code words. Referring to Fig. 5, damaging the non-priority code word No. 6 such that the decoder assumes, as an incorrect code word No. 6, a code word which is one bit shorter, will result in the fact that it is also no longer possible to correctly decode code word No. 7, since the last bit of the correct code word No. 6 is interpreted as being the start of the next code word No. 7. Therefore, an error in code word No. 6 will lead to the fact that, at a very high probability, it will no longer be possible, due to a sequence error, to correctly decode any code words following it even in case they have not been adversely affected by a transmission error.

It is the object of the present invention to render code words of variable lengths more error-robust.

This object is achieved by an apparatus for producing a data stream in accordance with claim 1, by an apparatus for reading a data stream in accordance with claim 12, by a method for producing a data stream in accordance with claim 18 and a method for reading a data stream in accordance with claim 19.

The present invention is based on the realization that the robustness of a data stream toward transmission errors and, in particular, toward sequence errors with code words of variable lengths can be decisively increased when the data stream is not written only in one direction of writing but is written, additionally, in the other direction of writing. In the most general case, a data stream will always have a start and an end. In the prior art, in the simplest case, the data stream was written onto, starting from the starting point, until it was completed. Thereby it was possible that a transmission error in the first code word could result in that the entire data stream could no longer be decoded correctly, even if all other code words

were transmitted correctly. In accordance with the invention, such a data stream may be written such that the first half of the data stream is written starting from the start of the data stream, whereas the second half of the data stream is written starting from the end of the data stream. Even from this simple example, it can be seen that a transmission error in the first half of the data stream no longer has the effect that code words of the second data stream can also no longer be decoded correctly due to sequence errors. This is the case because the decoder knows that after half of the data stream it must continue reading starting from the end of the data stream, to be precise in the opposite direction of reading. Thus, a certain error robustness is obtained merely due to reversing the direction of writing/the direction of reading with virtually no extra effort.

As has already been mentioned, code words with variable lengths are written into a data stream using raster points such that a decoder can decode with a limited number of sequence errors since, by definition, certain code words start at raster points. For maximum error robustness, it will, in principle, be desirable to have a raster which is as narrow as possible, such that a decoder can find the correct starting points of as many code words as possible. On the other hand, an increase in the number of raster points, i.e. a reduction of the segment length, will result in that fewer and fewer code words which, as is known, have variable lengths, completely fit into the raster, which is why measures are taken for the end sections of the same to be written into other segments in order to be able to be detected correctly in decoding. This leads to an increasing additional effort with a raising number of raster points and with a reduction in the segment length.

In the prior art, code words were written merely in one single direction of writing, starting from a raster point, as has been explained with reference to Figures 5 and 6. In

accordance with the invention, code words are now also written in the opposite direction of writing, starting from raster points, which causes the number of the code words which can be written starting at raster points to double, in the best case, essentially without any additional effort. By writing the data stream by means of a device for writing in a first direction of writing starting from a reference point and by means of a second device for writing in a second direction of writing which is opposite to the first direction of writing, starting from a different reference point, it becomes possible to not only utilize "one side" of a reference point, but both sides of a reference point for error robustness, i.e. for protection against propagation or sequence errors. Depending on the form of implementation, every other code word can be written in the same direction, for example, and every remaining code word can be written in the other direction. On the other hand, the code words of variable lengths can be divided up into different sets of code words, for example in accordance with their priority, such that, for example, all code words of the first set are written in the first direction of writing, starting at raster points, and all code words of the second set can be written in the second direction of writing, starting at raster points.

In addition, remainders of code words may be written in the same direction of writing as the starting sections of the code words or, alternatively, in the opposite direction of writing. It is evident that measures must be taken in order for a decoder, i.e. an apparatus for reading the data stream, to always be fully aware of which direction of writing has been used in writing. This may either be specifically set or be transmitted as side information to the data stream of code words of variable lengths. The same applies also to the segment lengths, wherein the segment length may either be equal or vary over the entire data stream, wherein the current segment length can of course also be specifically set in a decoder or can be transmitted

via side information together with the code words of variable lengths.

Preferred embodiments of the present invention will be explained in detail below with reference to the attached drawings, in which:

Fig. 1 shows an inventive apparatus for writing an error-robust data stream;

Fig. 2 shows an inventive apparatus for reading an error-robust data stream;

Fig. 3 shows a procedural diagram of the inventive method by means of three sets of code words of variable lengths;

Fig. 4 shows a procedural diagram for illustrating the inventive method for reading a data stream which has been produced in accordance with Fig. 3;

Fig. 5 shows a data stream which is produced by a known apparatus and in which the priority code words are exposed to error propagation;

Fig. 6 shows a data stream in which sorting by priority code words and non-priority code words has been carried out.

Before Fig. 1 will be described in more detail, it should be noted that encoding with code words of variable lengths is also referred to as entropy encoding in the art. One representative example of entropy encoding is the so-called Huffman encoding. In principle, in Huffman encoding, the information symbols to be encoded are statistically examined in order to determine shorter code words for the information symbols occurring more frequently than for information symbols occurring less frequently. In a complete Huffman code, all code words are terminated ends

or branches of a code tree. For example, a Huffman decoder serially reads in a data stream with Huffman code words and, put graphically, jumps to a branching of the specified code tree with each bit that it reads in additionally until, after a certain number of jumps, which corresponds to the number of bits of the code word, i.e. to the length of the code word, it arrives at a branch end which does not have any further branching and is therefore a code word. The decoder then knows that a new code word starts with the next bit. This process is repeated as often as required until the data stream has been completely read in. With each time that the Huffman encoder jumps back to the starting point, i.e. to the root of the tree, a code word is present at its point of origin. Since the lengths of the code words are implicitly specified by the code words themselves or by the code tree known in the encoder and in the decoder, it can be seen that an interference in the data stream which leads to a reversal of a bit misleads the decoder in the code tree, so to speak such that it ends up with a different code word, i.e. an incorrect code word, which is very likely to have a different length from the correct code word. In this case, the decoder will, once it has arrived at the incorrect code word, jump back and, due to the bits then following, again move from one branching point to another in the code tree. However, it is not possible for the decoder to avoid a sequence error, unless it coincidentally ends up on the "correct track".

Therefore, error protection, as is provided by the present invention, must be performed in order to ensure error-robust transmission. The apparatus for producing a data stream of code words of variable lengths in accordance with the present invention may therefore act as a sending or output stage of a Huffman encoder, as it were, whereas the apparatus for reading a data stream of code words of variable lengths may act as a receiving or input stage of a Huffman encoder. It can be seen from this that the present invention is not only applicable to Huffman encoders, but

to any code having code words of variable lengths which is susceptible to sequence errors.

Figure 1 shows an apparatus 10 in accordance with the invention for generating an error-robust data stream at an output 12, when code words of variable lengths are input into the apparatus 10 at an input 14. The apparatus includes a first device 16 for writing in a first direction of writing, starting from a first reference point, and a second device 18 for writing in a second direction of writing, starting from a second reference point. Depending on the complexity of the apparatus 10, the code words of variable lengths may both be applied to both devices 16 and 18 for writing, as is illustrated in Figure 1 by a simple branching point 20 and a corresponding combination point 22. The selection as to which code words are written in which direction, and/or as to which sections of code words are written in which direction, would then be made by devices 16 and 18. Instead of the node 20, a demultiplexer may be present alternatively, which supplies certain code words, for example code words of a set of code words, to the first device 16, and supplies certain code words to the second device 18. By analogy therewith, the combination point 22 would then be implemented by a multiplexer multiplexing the error-robust data stream 12. Other devices, which would be controlled correspondingly, for supplying the two devices 16 and 18 with the code words of variable lengths are apparent for those skilled in the art in view of the present description.

An apparatus 30 for reading an error-robust data stream, which apparatus is complementary to the apparatus 10 for producing a data stream, shown in Figure 1, is shown in Figure 2. Apparatus 30 includes an input 32, where the error-robust data stream is entered after transmission via a radio link for example, in order to obtain, again, at a starting point 34, the code words of variable lengths which have been fed into the input 14 of the apparatus 10 in

Figure 1. Apparatus 30 for reading the data stream includes a first device 36 for reading in the first direction, starting from the first reference point, and a second device 38 for reading the data stream in the second direction, starting from a second reference point.

It is evident that apparatus 30 also contains a branching point 40 and a combination point 42, the feeding-in of the error-robust data stream into the two devices 36 and 38 taking place, for example, based on a specifically set algorithm or based on side information which may also be transmitted, together with the error-robust data stream, from the sender, i.e. the apparatus 10 in Figure 1, to the receiver, i.e. the apparatus 30 in Figure 2.

Fig. 3 illustrates, by means of an example, the inventive method for writing code words of variable lengths. In the example, there are 15 code words of variable lengths 30 which are preferably divided up into a first set having 6 code words 1 to 6, into a second set also having 6 code words 7 to 12 and into a third set having the remaining 3 code words 13 to 15. As is shown in Fig. 3, code words 30 have variable lengths.

In accordance with a preferred embodiment of the present invention, the segment length, i.e. the length of the segment, is longer than the length of the longest code word of the first set. The code words of the first set are arranged at raster points 41 to 46, wherein, for the last segment No. 6, a raster point is indicated by a dotted line, which raster point is not used, however, since the end 47 of the data stream can also be considered as a raster point as it were and since the raster point indicated by a dotted line is thus superfluous. The first segment No. 6 is therefore longer than the other segments, which is completely irrelevant for the present invention, however. Generally speaking, the segments may have any lengths, which change within the data stream, it being

understood that the current length of a segment must be known to the decoder so that the inventive advantages can be utilized.

Firstly, the code words of the first set are written into the data stream in a step a), which results in a fragmentary data stream indicated by 31, in which the code words of the first set are written into a respective segment from left to right, as is indicated by arrows 48 which are to symbolize the direction of writing in the entire Fig. 3. Since the segment length is selected to be longer than the longest length of a code word of the first set, only one single attempt is needed for step a). In case the segments are shorter, more attempts may be required accordingly.

Now the code words of the second set are written into the data stream 31 in a step b). In order to achieve high error robustness, the code words of the second set are not written from left to right like the code words of the first set, but are written from right to left, starting from the second raster point, respectively, e.g. the raster point 42 for the first segment, as is indicated by the respective arrow of writing direction. The writing of the code words of the second set takes place in accordance with a predetermined assignment rule which says, in the example selected, that the first code word of the second set is to be written in the same segment as the first code word of the first set, however always on the condition that there is still room in this segment. The data stream 32 resulting from the first attempt shows that in the first segment there was only so much room for writing the starting section of code word No. 7.

In contrast to the prior art, where the second part of code word No. 7 would have been written into the second segment, the second half of code word No. 7, i.e. 7 b), is stored for writing it into the data stream in a second attempt in

accordance with a predetermined regulation, i.e. in accordance with an regulation which must also be known to the decoder. Fig. 3 clearly shows that in the second segment, there was still enough room between code word Nos. 2 and 8 for the final section of code word No. 7 to be entered. In case there had not been enough room, the third section of the code word would have been entered into segment No. 3. Thus, in Fig. 3, the predetermined regulation for entering code word No. 7 into the data stream consists in proceeding by one segment in each case. Of course, one may also proceed by two segments or by three or more, such that, as a consequence, the second segment 7 b) could then be written, instead of the second segment, into the third, into the fifth in the next attempt, etc. The order of segments which is used to accommodate the second part of section 7 somewhere is arbitrary. However, it must be transparent to the decoder so that the re-sorted data stream can be re-read.

The code words of the third set 13 to 15 are now to be entered into the resulting data stream 33, which is also still fragmentary. By analogy with step b), this is done preferably by the same assignment rule such that the first code word of the third set is assigned to the first segment, that the second code word of the third set is assigned to the second segment, that the third code word of the third set is assigned to the third segment, etc. This assignment rule is entirely arbitrary for the third set and may also be different from the assignment rule for the second set, with each code word of a set being assigned to a different segment in accordance with the invention. Similarly, the direction of writing can also be selected arbitrarily for each set. Preferably, an alternating writing direction order is used. Alternatively, however, it is also possible to write two adjacent sets using the same direction of writing. In principle, the writing direction may also altered within a set.

The first attempt in step c) was successful only in that the first section of code word No. 15 was entered, resulting in a fragmentary data stream 34. Code words 13, 14 and the second section of code word 15, i.e. 15 b) are stored for being accommodated in the second, third, fourth, fifth and sixth attempts, wherein the second section 15b could be accommodated in the fourth segment in the second attempt (data stream 35), wherein nothing could be accommodated in the third attempt, wherein the starting section of code word 14 could be accommodated in the fourth attempt (data stream 36), wherein the final section of code word 14, i.e. 14b could be accommodated in the fifth attempt (data stream 37) and wherein, finally, the first code word of the third set could be entered in the sixth segment in the sixth and final attempt, which results in the error-robust data stream 38 for the example illustrated here. The method described using Fig. 3 ensures that the length of the error-robust data stream exactly corresponds to the sum of the lengths of the code words of variable lengths, which is self-evident for the purposes of entropy encoding for data reduction. However, the present invention is not limited to the error-robust data stream having the minimal length, since error robustness is not affected by any filler bits that may be present.

When regarding the robust data stream shown in Fig. 3, it can be seen that the start of code word No. 8, i.e. raster point 43, is entirely independent of the end of code word No. 7. Moreover, the start of code word No. 9, i.e. raster point 44, is entirely independent of the end of code word No. 8. Additionally, it should be noted that due to the opposite writing order, a data error in code word No. 1 in the first segment, for example, which leads to the fact that the incorrect code word is one bit shorter than the correct code word No. 1 due to the data error, does not lead to a destruction of the starting section of code word No. 7a, since the latter was written from right to left instead of from left to right. In case it had been written

from left to right, a decoder would take the remaining bit from the initially correct code word No. 1 as the starting bit of code word No. 7, which would result in a sequence error from 1 to 7. However, this sequence error would not propagate to 8, since code word No. 8, again, is entirely independent of code word No. 7, since the writing order was chosen to be from right to left. In case the writing order of code word No. 8 is equal to the writing order of the code words of the first set, the error would not propagate from 7 to 8 either, since code word No. 8 would be written adjacent to code word No. 2 before the second part 7b due to the assignment rule and is, therefore, not influenced by an incorrect section 7b.

By means of an appropriate example, Fig. 4 shows the operation of the apparatus for reading the error-robust data stream 38. Initially, the code words of the first set are extracted from the error-robust data stream in step a). For this purpose, the inventive apparatus, which may be coupled to a Huffman decoder, reads the code word of the first set starting from the first raster point 41, reads code word No. 2 of the first set starting from the second raster point 42, etc., until all code words 1 to 6 of the first set have been read in. It is self-evident that the apparatus for reading the data stream selects the same direction as has been used by the apparatus for producing.

Subsequently, the code words of the second set are extracted from the remaining data stream 50 in step b). Here, the decoder jumps to the second raster point 42 of the first segment and obtains the starting section of code word 7 of the second set (the first segment is now empty), whereupon it does not read in the second section 7b, but 7a is first stored in order to then read in the second code word of the second set starting from the second raster point of the second segment, etc. The result is a residual data stream 51 in which the first segment has been completely emptied. Since the decoder does not now read the

code word 7 continuously, but always reads segment by segment on the basis of the assignment rule used for the apparatus for producing the data stream, the error robustness which has already been described and which strongly reduces propagation of sequence errors is ensured.

In a second attempt for extracting the code words of the second set, the second part of code word 7b is now read in the second segment in accordance with the existing writing direction, whereupon only code words of the third set remain in the resulting data stream 52, and the second segment is empty. These are extracted in step c), wherein the starting section of code word 15 has been initially determined in a first attempt, which is not stored however, since code word 15 has not been found complete in the third segment. The third segment is now empty. In a second attempt, code word 15 can be found complete. However, the search for code word 14 in segment 3 and for code word 15 in segment 14 remained without success, which can be seen by the data stream 54. Nevertheless, in the fourth attempt, the search for code word 14 in the fifth segment lead to a positive result. However, code word 14 was not complete, which is why the starting section 14a was stored in order to examine the remaining data stream 55 in a fifth attempt and to fully read in, in a final sixth attempt, data stream 56, which now only consists of the sixth segment and of code word 13.

Even though in the previous example merely a division of code words into a starting section and a final section was illustrated by way of example, any type of division is possible in principle. Error-robust decoding will be ensured as long as the decoder observes the assignment of code words of the second set or of the third set and of further sets to different segments, respectively. Moreover, it is obvious that the sorting of the final sections of code words into the data stream is arbitrary as long as the decoder or the read-in circuit upstream of the decoder

knows exactly which predetermined regulation has been carried out in the encoder.

In order to once again underline the advantages and/or the operation of the present invention, reference is made to the error-robust data stream No. 38 of Figure 3. When looking at the first segment between the raster points 41 and 42, it can be seen that code word No. 1 is written from left to right, starting from the first raster point 41, as is clearly indicated by the arrow drawn underneath. The first part of code word No. 7, i.e. 7a, however, is written from right to left, starting from the second raster point 42. If both code words No. 1 and No. 7 or 7a were written into the data stream only from left to right, the start of code word 7 or the starting point of the starting section 7a of code word 7 would depend on the end of code word 1. Therefore, a transmission error in code word 1 would almost inevitably also lead to a sequence error in code word 7. However, if code word 7 is written in the opposite direction of writing, starting from the second raster point 42, in accordance with the invention, the starting point of code word 7 or of starting section 7a of code word 7 no longer depends on code word 1 but is determined by the raster or raster point 42. A decoder will always know this starting point, which is why an error in code word 1 will not lead to an error in code word 7. It can be seen from the error-robust data stream 38 of Figure 3 that the first section 7a and the second section 7b of code word No. 7 are both written in the same direction of writing. However, this is not compulsory. Of course, the second section 7b of code word 7 may also be written from left to right and would then start at the end of the second code word No. 2.

If the raster points are chosen such that the segment lengths are longer than the longest length of a code word of the first set, no segment will be filled in completely by the code word of the first set, as can be seen, for example, from the data stream 31 of Figure 3. In this case,

the number of code words which can be written starting at raster points is actually doubled without there being any need of providing one single additional raster point.

Claims

1. Apparatus (10) for generating a data stream (38), which comprises two reference points (41 - 47), of code words of variable lengths, the apparatus comprising:

a first device (16) for writing at least a part of a code word into the data stream in a first direction of writing, starting from a first reference point;

a second device (18) for writing at least a part of a code word into the data stream in a second direction of writing, which is opposite to the first direction of writing, starting from the other reference point.

2. Apparatus as claimed in claim 1, wherein the two reference points of the data stream are the start (41) and the end (47) of the data stream, respectively.

3. Apparatus as claimed in claim 1, wherein the first writing device (16) is arranged so as to write a starting section of a code word, and wherein the second writing device (18) is arranged so as to write at least a part of the remainder of the same code word.

4. Apparatus as claimed in claim 1, wherein the data stream comprises a multitude of raster points (41 - 46) as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, the first writing device (16) being arranged so as to write a first code word which starts at a first raster point of a segment, and the second writing device (18) being arranged so as to write a second code word which starts at the second reference point of the segment.

5. Apparatus as claimed in claim 1, wherein the data stream comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, the first writing device (16) being arranged so as to write a starting section of a first code word at a first raster point of a first segment and to write a starting section of a second code word at a first raster point of a following segment, and the second writing device (18) being arranged so as to write the remainder of the first code word starting from the second reference point of the second segment and to write the remainder of the second code word starting from the second reference point of a further segment, respectively.

6. Apparatus as claimed in any of the preceding claims, wherein the code words are divided up into a plurality of sets of code words, the first device (16) for writing being arranged so as to write each code word of the first set into the data stream, starting from a first reference point of a segment, and the second writing device (18) being arranged so as to write each code word of the second set into the data stream, starting from a second reference point of a respective segment.

7. Apparatus as claimed in claim 6, wherein the second writing device (18) is arranged so as to write starting from the second reference point of the segment into which the first writing device (16) has written, wherein, if the respective code word of the second set is longer than a vacant space in the segment, the part of the code word of the second set which fits into the vacant space is written into the segment, and the remainder is stored.

8. Apparatus as claimed in claim 6 or 7, wherein the second writing device (18) is arranged so as to become active only once all code words of the first set have been written into the data stream.

9. Apparatus as claimed in claim 8, wherein the second writing device (18) is arranged so as to write the remainder of the code word to the end of a code word of the second set as a reference point into the data stream.

10. Apparatus as claimed in any of claims 6 to 9, wherein the code words of the second set are assigned to segments in accordance with a predetermined assignment rule, such that each code word of the second set is assigned to a different segment, and wherein the second writing device (18) is arranged so as to write, in the event that a code word of the second set no longer fits into the assigned segment, the remainder into a non-fully occupied other segment, after it has processed all remaining segments with the other code words of the second set.

11. Apparatus as claimed in any of claims 4 to 10, wherein the code words are divided up into at least three sets, the first writing device (16) being arranged so as to write the code words of the first set starting from first raster points of segments, the second writing device (18) being arranged so as to write the code words of the second set starting from the other raster points of the segments, the first or second writing device (16, 18) further being arranged so as to write the third set starting from ends of the code words of the first and the second set, respectively.

12. Apparatus (30) for reading a data stream (32) which comprises two reference points, starting from which at least a part of a code word is written in a first or

second writing direction, the apparatus comprising the following:

a first apparatus (36) for reading, starting from the first reference point, in a first direction of reading which corresponds to the first direction of writing;

and a second device (38) for reading, starting from the second reference point, in a second direction of reading which is opposite to the first direction of reading.

13. Apparatus as claimed in claim 12, wherein the data stream comprises a multitude of raster points as reference points, the raster points specifying a raster, two adjacent raster points defining a segment, wherein the data stream comprises a plurality of sets of code words, a first set of code words being written in the first direction and a second set of code words being written in a second direction, the code words of the second set being assigned to segments of the data stream in accordance with a predetermined assignment rule, such that each code word of a set is assigned to a different segment, the apparatus further comprising the following:

a control device (40) for supplying the code words of the first set to the first writing device (36), the code word of the first set starting at a raster point, and for supplying the code words of the second set to the second reading device (38), wherein, in accordance with the predetermined assignment rule, one jumps to corresponding raster points, wherein it is verified, if no code word is found at a reference point, whether code words of the second set are present at corresponding raster points in accordance with the assignment rule and wherein, after all code words of the second set have been read, one jumps to a

different raster point in accordance with the predetermined rule, in order to obtain all code words of the second set completely.

14. Apparatus as claimed in claim 13, wherein, if only one starting section of a code word is read by a writing device in one segment, this starting section is stored.

15. Apparatus as claimed in any of the preceding claims, wherein the code words are Huffman code words.

16. Apparatus as claimed in any of the preceding claims, wherein the code words represent information symbols and wherein code words of the first set represent more significant information symbols than code words of the second set or of further sets.

17. Apparatus as claimed in claim 16, wherein the information symbols are spectral values of an audio signal, and wherein the code words of the first set are spectral values which are significant from a psycho-acoustic point of view and which are to be protected from error propagation due to a transmission error in the data stream.

18. Method (10) for generating a data stream (38), which comprises two reference points (41) to (47), of code words of variable lengths, the method comprising the following steps:

writing at least a part of a code word into the data stream in a first direction of writing, starting from a first reference point;

writing at least a part of a code word into the data stream in a second direction of writing which is

opposite to the first direction of writing, starting from the other reference point.

19. Method (30) for reading a data stream (32) which comprises two reference points, from which at least a part of a code word is written in a first and a second direction of writing, respectively, the method comprising the following steps:

reading, starting from the first reference point, in a first direction of reading which corresponds to the first direction of writing; and

reading, starting from the second reference point, in a second direction of reading which is opposite to the first direction of reading.

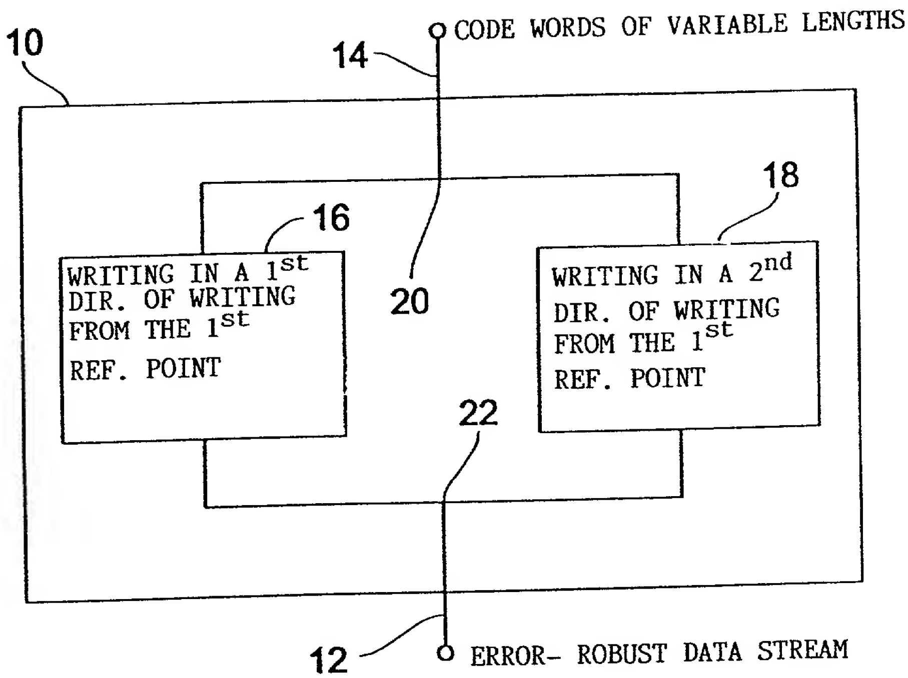
CODE WORDS OF VARIABLE LENGTHS
10
14
16
18
WRITING IN A 1st DIR. OF WRITING FROM THE 1st REF. POINT
20
WRITING IN A 2nd DIR. OF WRITING FROM THE 1st REF. POINT
22
12
ERROR- ROBUST DATA STREAM

Fig. 1

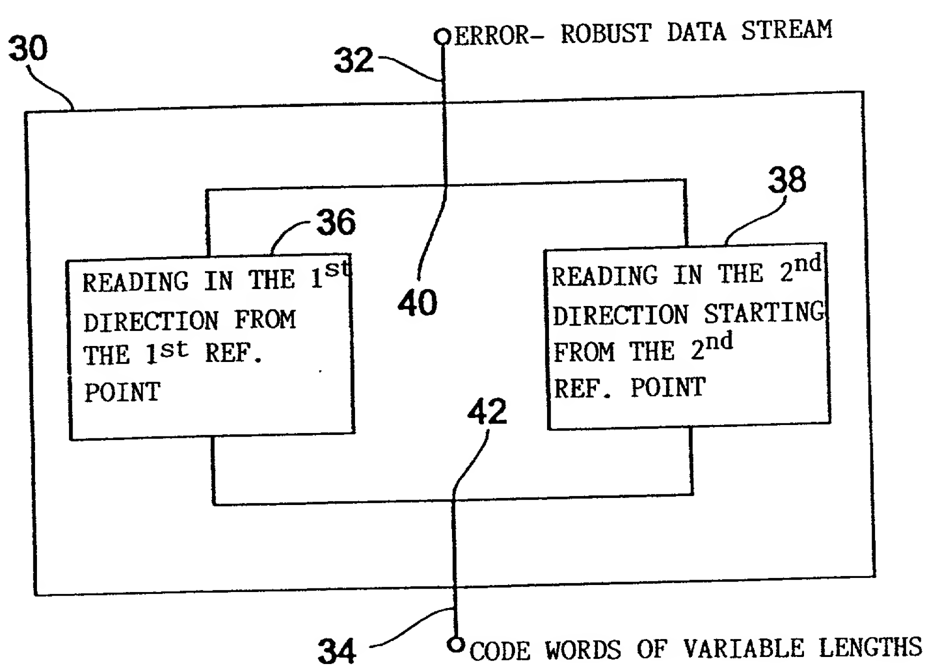
ERROR- ROBUST DATA STREAM
30
32
36
38
READING IN THE 1st DIRECTION FROM THE 1st REF. POINT
40
READING IN THE 2nd DIRECTION STARTING FROM THE 2nd REF. POINT
42
34
CODE WORDS OF VARIABLE LENGTHS

Fig. 2

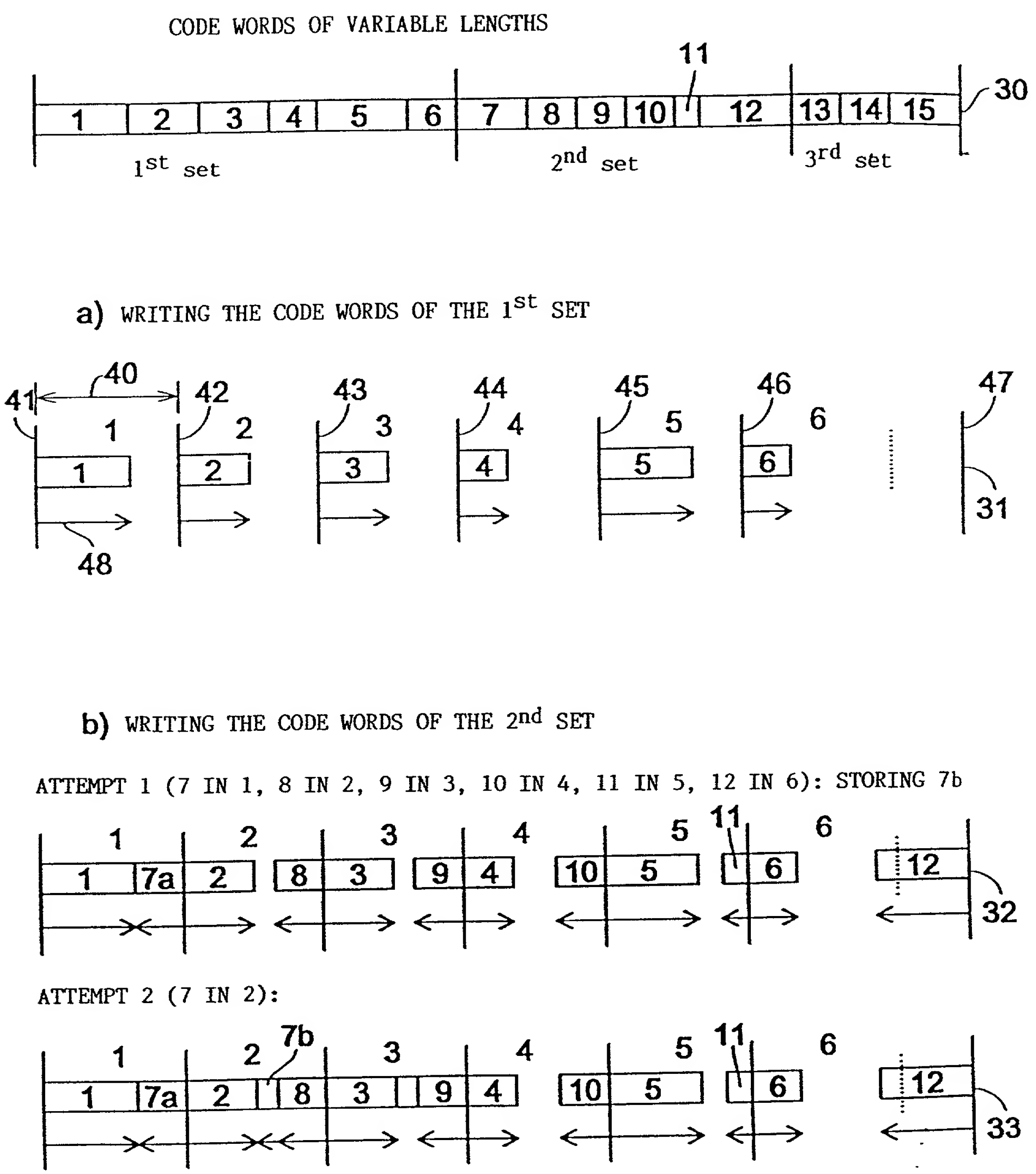
CODE WORDS OF VARIABLE LENGTHS
11
1
2
3
4
5
6
7
8
9
10
12
13
14
15
30
1st set
2nd set
3rd set
a) WRITING THE CODE WORDS OF THE 1st SET
40
41
42
43
44
45
46
47
31
48
b) WRITING THE CODE WORDS OF THE 2nd SET
ATTEMPT 1 (7 IN 1, 8 IN 2, 9 IN 3, 10 IN 4, 11 IN 5, 12 IN 6): STORING 7b
7a
32
ATTEMPT 2 (7 IN 2):
7b
33

Fig. 3

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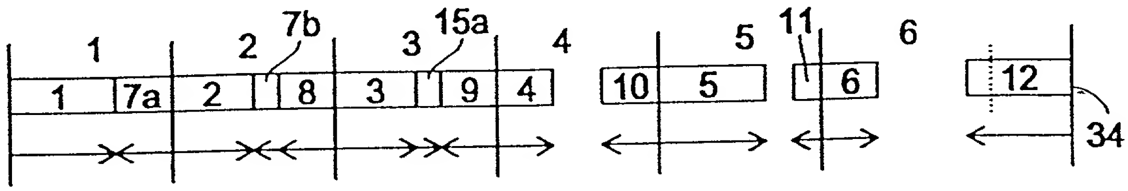
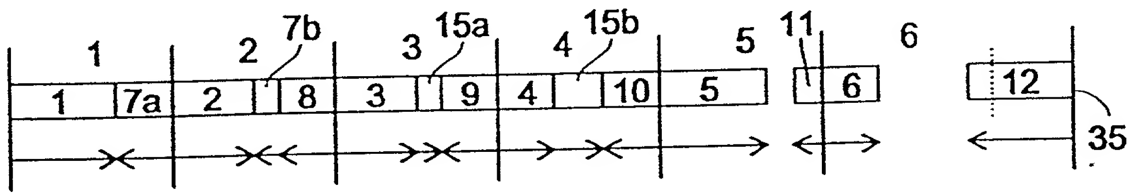
c) WRITING THE CODE WORDS OF THE 3rd SET

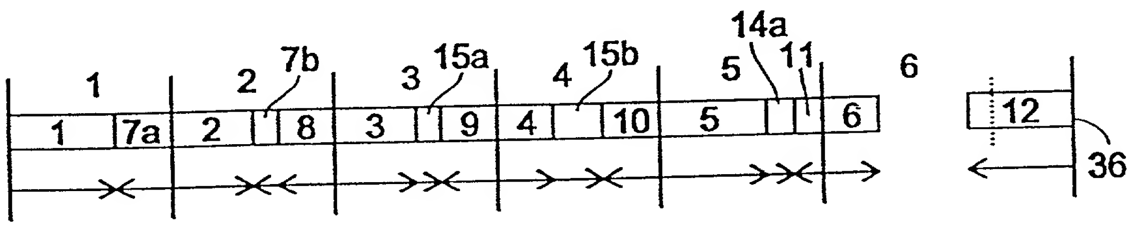
ATTEMPT 1 (13 IN 1, 14 IN 2, 15 IN 3): STORING 13, 14, 15b



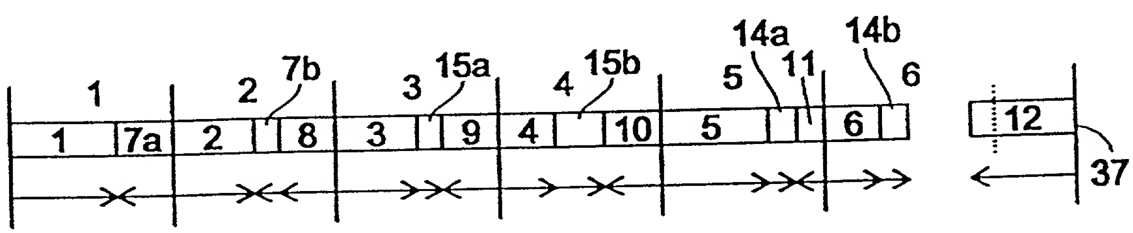
ATTEMPT 2 (13 IN 2, 14 IN 3, 15 IN 4): STORING 13, 14



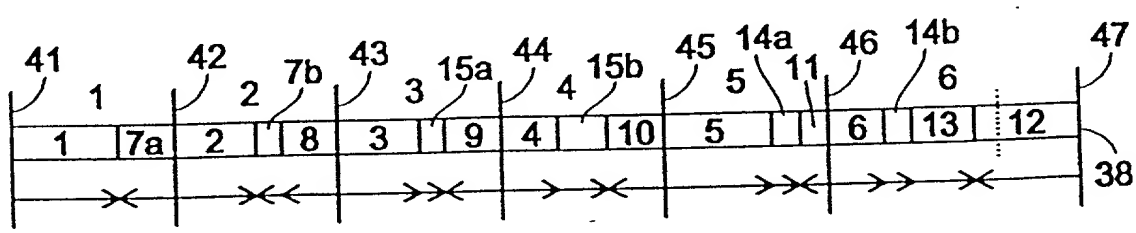
ATTEMPT 3 (13 IN 3, 14 IN 4): STORING 13, 14
ATTEMPT 4 (13 IN 4, 14 IN 5): STORING 13, 14b



ATTEMPT 5 (13 IN 5, 14 IN 6): STORING 13



ATTEMPT 6 (13 IN 6)

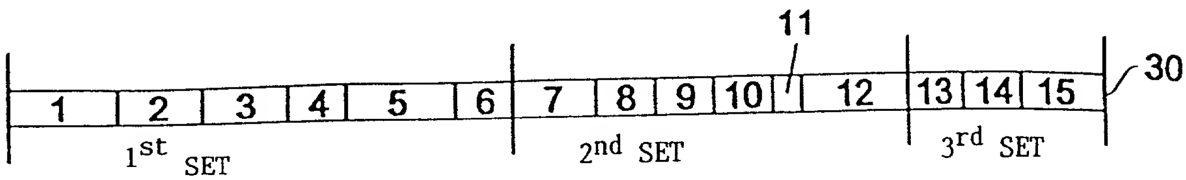


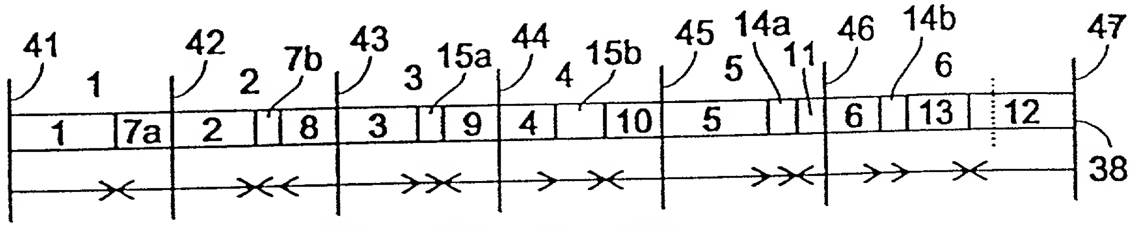
ERROR- ROBUST DATA STREAM

Fig. 3

09/913708

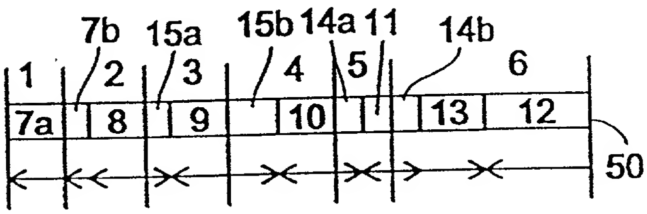
CODE WORDS OF VARIABLE LENGTHS





ERROR- ROBUST DATA STREAM

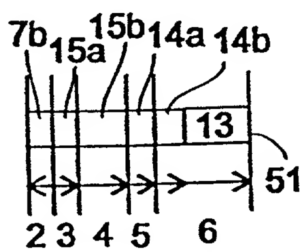
a)EXTRACTING THE CODE WORDS OF THE 1^{st} SET



b)EXTRACTING THE CODE WORDS OF THE 2^{nd} SET

ATTEMPT 1 (SEARCHING 7 IN 1, 8 IN 2, 9 IN 3, 10 IN 4, 11 IN 5, 12 IN 6)

STORING 7a



ATTEMPT 2 (SEARCHING 7 IN 2)

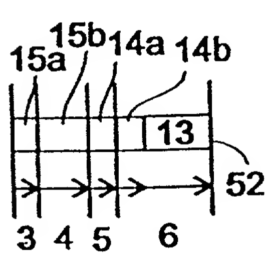
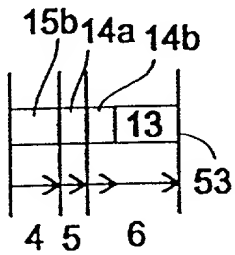


Fig. 4

09/913708

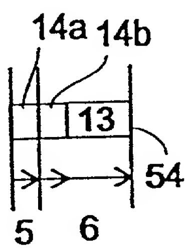
c) EXTRACTING THE CODE WORDS OF THE 3rd SET

ATTEMPT 1 (SEARCHING 13 IN 1, 14 IN 2, 15 IN 3)

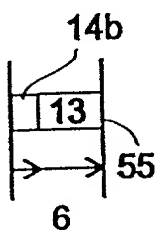


STORING 15a

ATTEMPT 2 (SEARCHING 13 IN 2, 14 IN 3, 15 IN 4)

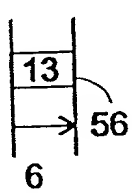


ATTEMPT 3 (SEARCHING 13 IN 3, 14 IN 4)
ATTEMPT 4 (SEARCHING 13 IN 4, 14 IN 5)



STORING 14a

ATTEMPT 5 (SEARCHING 13 IN 5, 14 IN 6)



ATTEMPT 6 (SEARCHING 13 IN 6)

Fig. 4

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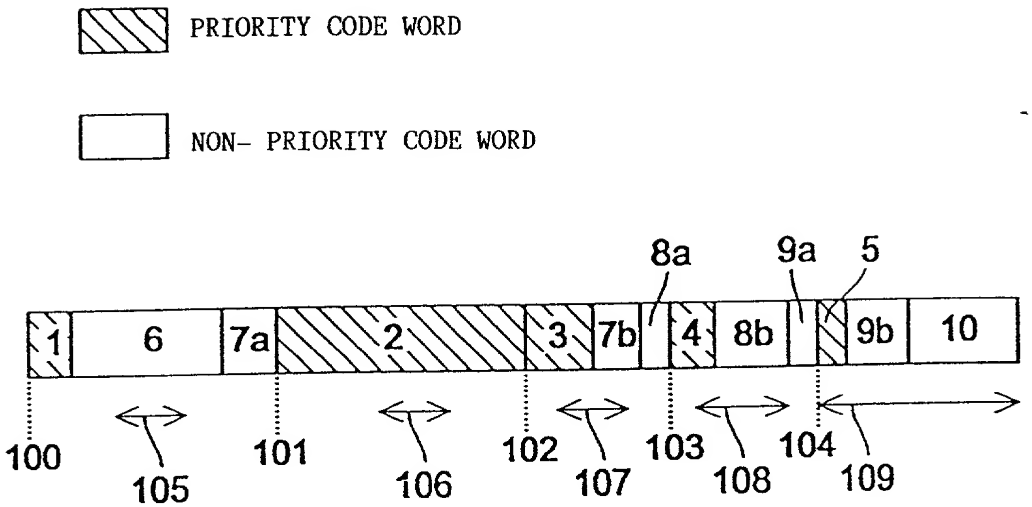

Fig. 5 (PRIOR ART)

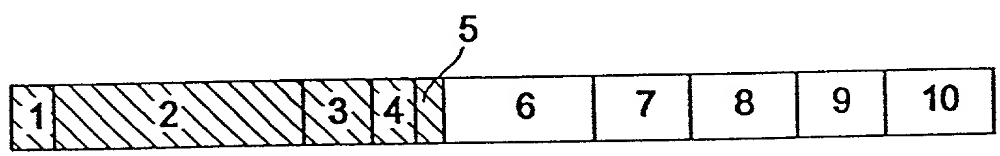

Fig. 6 (PRIOR ART)

3219 #3

OIPE JC10 SEP 24 2001 PATENT & TRADEMARK OFFICE

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Declaration and Power of Attorney for Patent Application
Erklärung für Patentanmeldungen mit Vollmacht

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____

____

deren Beschreibung hier beigefügt ist, es sei denn (in diesem Falle Zutreffendes bitte ankreuzen), diese Erfindung

☐ wurde angemeldet am ________ unter der US-Anmeldenummer oder unter der Internationalen Anmeldenummer im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesens (PCT) ________ und am ________ abgeändert (falls zutreffend).

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Ich erkenne meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Titel 37, Code of Federal Regulations, § 1.56 von Belang sind.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Apparatus and Method for Producing a Data Stream and Apparatus and Method for Reading a Data stream

the specification of which is attached hereto unless the following box is checked:

☒ was filed on 08-16-01 as United States Application Number or PCT International Application Number 09/913,708 and was amended on ________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

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Prior Foreign Applications
(Frühere ausländische Anmeldungen)

(Number) (Nummer)	(Country) (Land)	(Day/Month/Year Filed) (Tag/Monat/Jahr der Anmeldung)	Priority Not Claimed / Priorität nicht beansprucht
PCT/EP00/00314	Germany	17/01/00	☐
19907728.2	Germany	23/02/99	☐

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(Application No.) (Aktenzeichen) (Filing Date) (Anmeldetag)

(Application No.) (Aktenzeichen) (Filing Date) (Anmeldetag)

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(Application No.) (Aktenzeichen) (Filing Date) (Anmeldetag) (Status) (patented, pending, abandoned) (Status) (patentiert, schwebend, aufgegeben)

(Application No.) (Aktenzeichen) (Filing Date) (Anmeldetag) (Status) (patented, pending, abandoned) (Status) (patentiert, schwebend, aufgegeben)

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Gregory N. Clements – Reg. No. 30,713
J. Scott Young – Reg. No. 45,582
David P. Stitzel – Reg. No. 44,360

Send Correspondence to: Dougherty & Clements LLP
6230 Fairview Road, Suite 400, Charlotte, North Carolina 28210, USA

Direct Telephone Calls to: *(name and telephone number)*
704-366-6642
Ralph H. Dougherty

Vor- und Zuname des einzigen oder ersten Erfinders 1-00	Full name of sole or first inventor Ralph SPERSCHNEIDER
Unterschrift des Erfinders Datum	Inventor's signature Ralph Sperschneider Date September 6, 2001
Wohnsitz	Residence ~~Erlangen~~, Germany DEX
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Donato-Polli-Strasse 42
	D-91056 Erlangen, Germany
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of second joint inventor, if any Martin DIETZ
Unterschrift des zweiten Erfinders Datum	Second Inventor's signature Date
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Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Kleinreuther Weg 47
	D-90408 Nuernberg, Germany

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Gregory N. Clements – Reg. No. 30,713
J. Scott Young – Reg. No. 45,582
David P. Stitzel – Reg. No. 44,360

Send Correspondence to: Dougherty & Clements LLP
6230 Fairview Road, Suite 400, Charlotte, North Carolina 28210, USA

Direct Telephone Calls to: *(name and telephone number)*
Ralph H. Dougherty (704)366-6642

Vor- und Zuname des einzigen oder ersten Erfinders	Full name of sole or first inventor Ralph SPERSCHNEIDER
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz	Residence Erlangen, Germany
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Donato-Polli-Strasse 42
	D-91056 Erlangen, Germany
Vor- und Zuname des zweiten Miterfinders (falls zutreffend) 2-00	Full name of second joint inventor, if any Martin DIETZ
Unterschrift des zweiten Erfinders Datum	Second Inventor's signature Date September 6, 2001
Wohnsitz	Residence Nuernberg, Germany DEX
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Kleinreuther Weg 47
	D-90408 Nuernberg, Germany

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Gregory N. Clements – Reg. No. 30,713
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David P. Stitzel – Reg. No. 44,360

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Telefonische Auskünfte: *(Name und Telefonnummer)*

Direct Telephone Calls to: *(name and telephone number)*
Ralph H. Dougherty (704)366-6642

Vor- und Zuname des einzigen oder ersten Erfinders	Full name of: third inventor 3-00 Daniel HOMM
Unterschrift des Erfinders Datum	Inventor's signature Date September 6, 2001
Wohnsitz	Residence Erlangen, Germany DEX
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Wichernstrasse 18
	D-91052 Erlangen, Germany
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of fourth inventor, if any Reinhold BÖHM
Unterschrift des zweiten Erfinders Datum	Inventor's signature Date
Wohnsitz	Residence Nuernberg, Germany
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Etzlaubweg 12
	D-90469 Nuernberg, Germany

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: *(list name and registration number)*

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Gregory N. Clements – Reg. No. 30,713
J. Scott Young – Reg. No. 45,582
David P. Stitzel – Reg. No. 44,360

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Send Correspondence to: Dougherty & Clements LLP
6230 Fairview Road, Suite 400, Charlotte, North Carolina 28210, USA

Telefonische Auskünfte: *(Name und Telefonnummer)*

Direct Telephone Calls to: *(name and telephone number)*
Ralph H. Dougherty (704)366-6642

Vor- und Zuname des einzigen oder ersten Erfinders	Full name of: third inventor Daniel HOMM
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz	Residence Erlangen, Germany
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Wichernstrasse 18
	D-91052 Erlangen, Germany
Vor- und Zuname des zweiten Miterfinders (falls zutreffend) 4-00	Full name of fourth inventor, if any Reinhold BÖHM
Unterschrift des zweiten Erfinders Datum	Inventor's signature Reinhold Böhm ~~Date~~ September 6, 2001
Wohnsitz	Residence ~~Nuernberg~~, Germany DEX
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Etzlaubweg 12
	D-90469 Nuernberg, Germany

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